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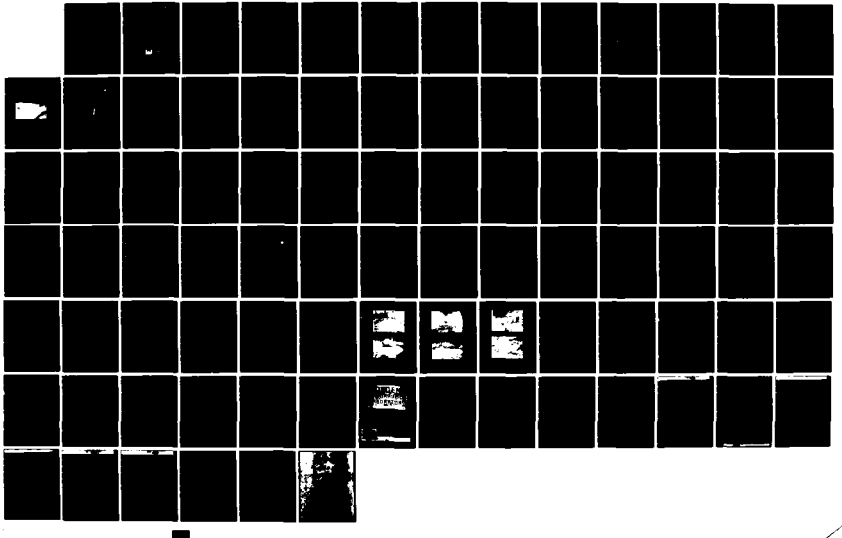

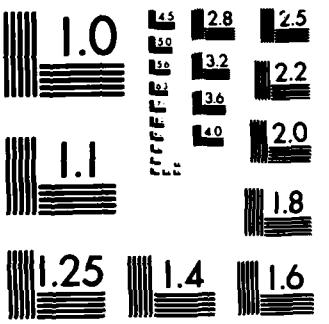

BLACKSTONE RIVER BASIN
WORCESTER, MASSACHUSETTS

GES RESERVOIR DAM
MA 00120

PHASE I INSPECTION REPORT
NATIONAL DAM INSPECTION PROGRAM

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS. 02154

AUGUST, 1978

UNCLASSIFIED

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Cover program reads: Phase I Inspection Report, National Dam Inspection Program; however, the official title of the program is: National Program for Inspection of Non-Federal Dams; use cover date for date of report.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

DAMS, INSPECTION, DAM SAFETY,

Blackstone River Basin
Worcester, Massachusetts

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Coes Reservoir Dam is an earthfill dam with a 700 foot long and 20 foot high embankment. Generally, the Coes Reservoir Dam is considered to be in fair condition and has been classified in the "High" hazard category. Based on size and hazard classifications, the test flood is one-half the probable maximum flood.

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DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
424 TRAPELO ROAD
WALTHAM, MASSACHUSETTS 02154

REPLY TO
ATTENTION OF:

NEDED-E

AUG 31 1979

Honorable Edward J. King
Governor of the Commonwealth of
Massachusetts
State House
Boston, Massachusetts

Dear Governor King:

Inclosed is a copy of the Coes Reservoir Dam Phase I Inspection Report, which was prepared under the National Program for Inspection of Non-Federal Dams. The report is based upon a visual inspection, a review of past performance, and a preliminary hydrological analysis. A brief assessment is included at the beginning of the report.

The preliminary hydrologic analysis has indicated that the spillway capacity for the Coes Reservoir Dam would likely be exceeded by floods greater than 17 percent of the Probable Maximum Flood (PMF), the test flood for spillway adequacy. Our screening criteria specifies that a dam of this class which does not have sufficient spillway capacity to discharge fifty (50) percent of the PMF, should be adjudged as having a seriously inadequate spillway and the dam assessed as unsafe, non-emergency, until more detailed studies prove otherwise or corrective measures are completed.

The term "unsafe" applied to a dam because of an inadequate spillway does not indicate the same degree of emergency as that term would if applied because of structural deficiency. It does indicate, however, that a severe storm may cause overtopping and possible failure of the dam, with significant damage and potential loss of life downstream.

It is recommended that within twelve months from the date of this report the owner of the dam engage the services of a professional or consulting engineer to determine by more sophisticated methods and procedures the magnitude of the spillway deficiency. Based on this determination, appropriate remedial mitigating measures should be designed and completed within 24 months of this date of notification. In the interim a detailed emergency operation plan and warning system should be promptly developed. During periods of unusually heavy precipitation, round-the-clock surveillance should be provided.

NEDED-E
Honorable Edward J. King

I have approved the report and support the findings and recommendations described in Section 7, with qualifications as noted above. I request that you keep me informed of the actions taken to implement these recommendations since this follow-up is an important part of the non-Federal Dam Inspection Program.

A copy of this report has been forwarded to the Department of Environmental Quality Engineering, the cooperating agency for the Commonwealth of Massachusetts. This report has also been furnished to the owner of the project, Coes Knife Company, 72 Coes Street, Worcester, Massachusetts 01603.

Copies of this report will be made available to the public, upon request to this office, under the Freedom of Information Act, thirty days from the date of this letter.

I wish to take this opportunity to thank you and the Department of Environmental Quality Engineering for the cooperation extended in carrying out this program.

Sincerely,

MAX B. SCHEIDER
Colonel, Corps of Engineers
Division Engineer

COES RESERVOIR DAM

MA 00120

BLACKSTONE RIVER BASIN
WORCESTER, MASSACHUSETTS

PHASE I INSPECTION REPORT
NATIONAL DAM INSPECTION
PROGRAM

NATIONAL DAM INSPECTION
PROGRAM

PHASE I INSPECTION REPORT

BRIEF ASSESSMENT

Identification No.: MA00120

Name of Dam: Coes Reservoir

Town: Worcester

County and State: Worcester County, Massachusetts

Stream: Tatnuck Brook, a tributary of the Blackstone River

Date of Inspection: July 24, 1978

Built in 1865, Coes Reservoir Dam is an earthfill dam with a 700-foot long and 20-foot high embankment. The Coes Knife Company buildings are located immediately downstream of the dam, and grinding grit fill from the company has been placed on the dam over the years. A broad-crested spillway is located near the north abutment. The concrete weir is 38.5 feet long with a crest elevation (El) of 501. Normal discharge flows over the weir, down a stone-lined channel, and into Lower Coes Pond. There is an abandoned 36-inch diameter intake conduit which has been sealed off at the upstream face of the dam. Discharge from the conduit was into a tailrace channel which is located at the toe of the dam and leads to the spillway discharge channel.

The only plans, specifications, or computations available from the Owner, State, or County offices on the design, construction, and repair of this dam are a topographic survey of the spillway area, dated July 1956, and a hydraulic and model analysis of the spillway, dated December 1958.

Due to its age, Coes Reservoir Dam was neither designed nor constructed according to current approved state-of-art procedures. Based upon the visual

inspection at the site, the lack of engineering data, and the limited evidence of operational or maintenance procedures, it was determined that various conditions must be corrected to assure the continued performance of this dam. Generally, the Coes Reservoir Dam is considered to be in fair condition and has been classified in the "high" hazard category.

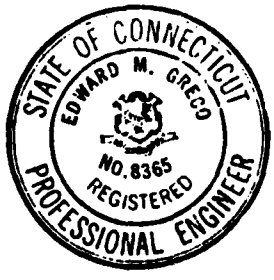
The following visible signs of distress indicate a potential hazard at the site: erosion and lack of protection on the steep upstream face of the dam; deterioration of the concrete and stone training walls of the spillway; cracking and collapse of the concrete side channel in the discharge channel; seepage from the upstream wall of the tailrace channel and north wall of the discharge channel; and a dense growth of brush and trees on the dam embankment and the downstream areas.

Hydraulic analyses indicate that the existing spillway can discharge a flow of 1,458 cfs at El 506.3 which is the low point on the crest of the dam . Based on size and hazard classificaions, in accordance with Corps guidelines, the test flood is one-half the probable maximum flood. An inflow test flood of 10,000 cfs adjusted for surcharge storage results in an outflow of 8,500 cfs. This will overtop the main dam by about 3.4 feet. The spillway is inadequate since it can discharge only 17 percent of the test flood before the dam is overtopped. Since overtopping could result in complete failure of the dam, it is recommended that a definite surveillance plan and warning system be developed for use during periods of unusually heavy rains and/or runoff. This system should be coordinated with the operators of the upstream reservoirs (Holden No. 1 and No. 2).

It is recommended that the Owner employ the services of a qualified consultant to (1) evaluate the stability of the dam and seepage along the upstream wall of the tailrace channel and (2) conduct a more detailed hydraulic and hydrologic study for the entire drainage area. It is also recommended that the Owner construct an adequate spillway based on the studies recommended above; repair the upstream embankment slopes by filling in eroded areas, flatten the slope and protect it with riprap; repair eroded concrete and loose stonework in the existing spillway; remove the concrete side channel from the discharge channel; clear trees and brush from the dam embankment and

downstream areas; and clear debris and trash from the spillway crest and downstream channel. The Owner should also implement a systematic program of inspection and maintenance.

The above recommendations should be implemented within a period of one to two years after receipt of the Phase I Inspection Report. An alternative to these recommendations would be draining the reservoir and breaching or removing the dam.



Edward M. Greco, P.E.
Project Manager
Metcalf & Eddy, Inc.

Connecticut Registration
No. 08365

Approved by:

Stephen L. Bishop, P.E.
Vice President
Metcalf & Eddy, Inc.

Massachusetts Registration
No. 19703

This Phase I Inspection Report on Coes Reservoir Dam has been reviewed by the undersigned Review Board members. In our opinion, the reported findings, conclusions, and recommendations are consistent with the Recommended Guidelines for Safety Inspection of Dams, and with good engineering judgment and practice, and is hereby submitted for approval.

Charles G. Tiersch

CHARLES G. TIERSCH, Chairman
Chief, Foundation and Materials Branch
Engineering Division

Fred J. Ravens Jr

FRED J. RAVENS, Jr., Member
Chief, Design Branch
Engineering Division

Saul Cooper

SAUL COOPER, Member
Chief, Water Control Branch
Engineering Division

APPROVAL RECOMMENDED:

Joe B. Fryar

JOE B. FRYAR
Chief, Engineering Division

PREFACE

This report is prepared under guidance contained in Recommended Guidelines for Safety Inspection of Dams, for a Phase I Investigation. Copies of these guidelines may be obtained from the Office of Chief of Engineers, Washington, D. C. 20314. The purpose of a Phase I Investigation is to identify expeditiously those dams which may pose hazards to human life or property. The assessment of the general condition of the dam is based upon available data and visual inspections. Detailed investigation, and analyses involving topographic mapping, subsurface investigations, testing, and detailed computational evaluations are beyond the scope of a Phase I investigation; however, the investigation is intended to identify any need for such studies.

In reviewing this report, it should be realized that the reported condition of the dam is based on observations of field conditions at the time of inspection along with data available to the inspection team. In cases where the reservoir was lowered or drained prior to inspection, such action, while improving the stability and safety of the dam, removes the normal load on the structure and may obscure certain conditions which might otherwise be detectable if inspected under the normal operating environment of the structure.

It is important to note that the condition of a dam depends on numerous and constantly changing internal and external conditions, and is evolutionary in nature. It would be incorrect to assume that the present condition of the dam will continue to represent the condition of the dam at some point in the future. Only through continued care and inspection can there be any chance that unsafe conditions be detected.

Phase I inspections are not intended to provide detailed hydrologic and hydraulic analyses. In accordance with the established Guidelines, the Spillway Test flood is based on the estimated "Probable Maximum Flood" for the region (greatest reasonably possible storm runoff), or fractions thereof. Because of the magnitude and rarity of such a storm event, a finding that a spillway will not pass the test flood should not be interpreted as necessarily posing a highly inadequate condition. The test flood provides a measure of relative spillway capacity and serves as an aid in determining the need for more detailed hydrologic and hydraulic studies, considering the size of the dam, its general conditions and the downstream damage potential.

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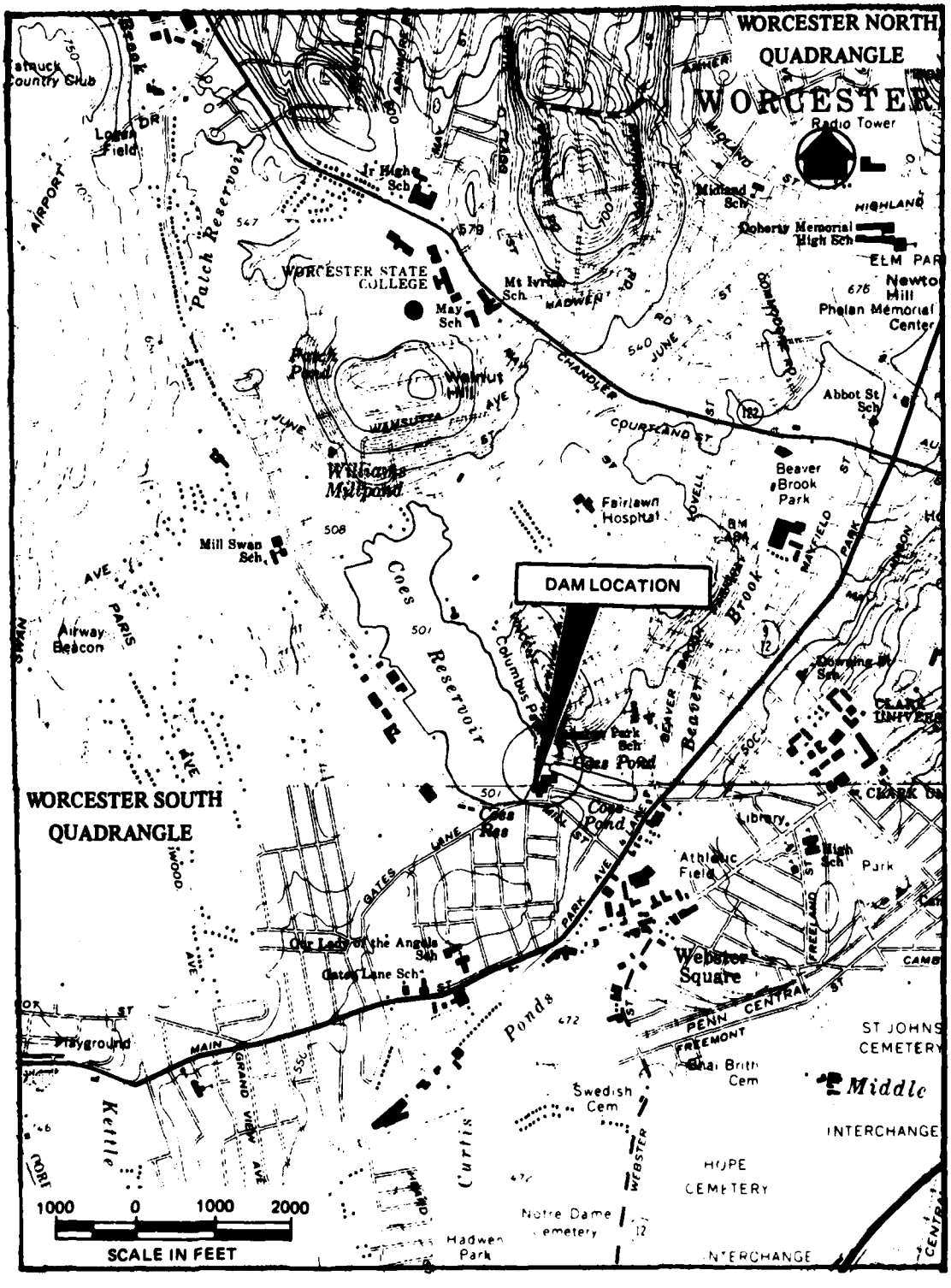
OVERVIEW
COES RESERVOIR
WORCESTER, MASSACHUSETTS

VIEW FROM UPSTREAM OF SOUTH ABUTMENT

Location and Direction of Photographs
Shown on Figure in Appendix B



LOCATION MAP - COES RESERVOIR DAM

NATIONAL DAM INSPECTION
PROGRAM

PHASE I INSPECTION REPORT

COES RESERVOIR

SECTION 1

PROJECT INFORMATION

1.1 General

a. Authority. Public Law 92-367, August 8, 1972, authorized the Secretary of the Army, through the Corps of Engineers, to initiate a national program of dam inspection throughout the United States. The New England Division of the Corps of Engineers has been assigned the responsibility of supervising the inspection of dams within the New England Region. Metcalf & Eddy, Inc. has been retained by the New England Division to inspect and report on selected dams in the State of Massachusetts. Authorization and notice to proceed was issued to Metcalf & Eddy, Inc. under a letter of May 3, 1978, from Ralph T. Garver, Colonel, Corps of Engineers. Contract No. DACW 33-78-C-0306 has been assigned by the Corps of Engineers for this work.

b. Purpose:

(1) Perform technical inspection and evaluation of non-Federal dams to identify conditions which threaten the public safety and thus permit correction in a timely manner by non-Federal interests.

(2) Encourage and assist the States to initiate quickly effective dam safety programs for non-Federal dams.

(3) Update, verify and complete the National Inventory of Dams.

1.2 Description of Project

a. Location. The dam is located in the City of Worcester, Worcester County, Massachusetts, on Tatnuck Brook, a tributary of the Blackstone River. Patch Reservoir and Patch Pond are located immediately upstream of Coes Reservoir. Downstream of the dam and Coes Pond, the stream joins Beaver Brook, which flows into Kettle Brook and eventually discharges into the Middle River (see Location Map and Watershed Plan Figure D-1).

b. Description of Dam and Appurtenances. Coes Reservoir Dam is mostly an earthfill dam, 700 feet long and 20 feet high (see Dam Plan and sections in Appendix B). The embankment also contains grinding grit fill from Coes Knife Company and miscellaneous fill from street demolition. Over the years, these materials were added to the dam to increase its width and height as well to dispose of waste from the grinding operation. The impervious core of the dam was constructed of oak and brick sheeting with a puddled trench. (See inspection list from the Worcester County Engineer's office, Appendix B). The crest of the dam is generally about 30 feet wide, however, in the abutment areas, the actual crest width is indeterminate because of extensive filling to develop Lakeside Avenue (north abutment) and a parking lot for Coes Knife Company (south abutment). The crest of the dam varies from El 506.3 to El 508.3. The upstream slope of the embankment slope is generally 1:1 (horizontal:vertical), except for the portion north of the spillway which is 5:1. The downstream slope is highly irregular due to dumping of grinding grit; the slope is generally 3:1 to 5:1, but a very flat area occurs near the abutments (40:1 at Lakeside Avenue) and a vertical stone wall exists at the toe of the dam. This wall is part of a tailrace channel that leads into the main discharge channel downstream of the spillway.

The spillway is a broad-crested weir constructed of stone masonry training walls; concrete-faced stone masonry side walls; and a concrete crest. The training walls are about 10 feet

long and form the sides to the approach channel. The crest, which is 38.5 feet long, is at El 501.0.

The spillway side walls are 5.4 feet high. There is a 1-foot-wide metal sill embedded in the upstream edge of the crest, and metal slides in the side walls which were previously used as a frame to support flashboards. There are also four steel I-beams embedded in the crest that were used to support a bridge over the spillway. The I-beams have been cut off approximately level with the top of the weir. The stone-lined downstream channel is 38 feet wide, 110 feet long, and slopes at about 7:1. The side walls are dry-stone masonry and are about 4 feet high. A concrete channel, 4 feet wide and 2 feet deep, is located on the bottom of the discharge channel along the north wall.

An abandoned intake conduit for a waterwheel is located 130 feet south of the spillway. This 36-inch diameter iron pipe has an intake upstream in the pond. Before it was cut off by steel sheet piling driven in the upstream face of the dam, the conduit carried flow beneath the dam and into a gatehouse at Coes Knife Company, located at the toe of the dam. A gate valve is located in the gatehouse, but it is rusted and inoperable. The flow from the waterwheel discharged into a tailrace channel, also located along the toe of the dam. The channel is 13 to 22 feet wide, 8 feet deep, and 150 feet long. It is made of vertical, dry-stone masonry walls and is recessed below the ground surface. This tailrace channel intersects the main discharge channel about 130 feet downstream of the spillway.

c. Size Classification. Coes Reservoir Dam is classified in the "small" category since it has a maximum height of 20 feet and a maximum storage capacity of 1,400 acre-feet.

d. Hazard Classification. The Coes Knife Company is located at the toe of the dam. In addition, highly developed residential areas on Coes Road and Lakeside Avenue are located

downstream of the dam. In the event of overtopping or complete failure of the dam, more than a few lives could be lost and considerable property damage could occur. Accordingly, the dam has been placed in the "high" hazard category.

e. Ownership. The dam is presently owned by the Coes Knife Company, 72 Coes Street, Worcester, Massachusetts 01603. Messrs. Jim Hillhouse and Joseph Lajeunesse (617-755-2573) granted permission to enter the property and to inspect the dam.

f. Operator. There are no operators of this dam since there are no existing operational features. The Coes Knife Company is located immediately downstream of the dam and as Owner occasionally inspects the dam and appurtenances.

g. Purpose of Dam. The dam was originally built to provide water to a waterwheel for operating machinery and for cooling purposes at the Coes Knife Company. The pond was also used for the production of ice at the Walker Ice Company which was located in the present-day Lakeside Avenue area. In 1936, the intake conduit to Coes Knife Company was cut off. Presently, the reservoir is primarily used for recreational activities, such as swimming and fishing.

h. Design and Construction History. According to information provided by the Owner, the original earth dam was designed by Loring Coes and built in 1865. It was raised in 1871 and 1872, and a final 4 feet was added in 1895. A road which originally crossed the pond was relocated along the crest of the dam, and a vehicular bridge was placed over the spillway to provide access to the Walker Ice Company, located in the Lakeside Avenue area. Previous inspection reports indicate that flashboards were in use on the spillway crest as early as 1931.

During the floods in March 1936, the dam was breached to a depth of 4 feet near the south abutment, and water flowed down Coes Street into Webster Square. During the flooding, it was found that the gate valve on the intake conduit was rusted and inoperable. Therefore, in December 1936, steel sheet piling was driven through the pipe to seal it off.

In late 1954 and early 1955, a plan to enlarge the spillway to 44 feet long and 8 feet high was discussed by Coes Knife Company and the Worcester County Commissioners. In the August 1955 hurricane, the water level rose to the crest of the dam. The embankment north of the spillway was partially washed out and the north wall of the spillway was damaged. Coes Knife Company was directed by the Worcester County Commissioners on September 16, 1955 (see Appendix B) to enlarge the spillway and provide a new outlet conduit, fill in the dam embankment, and riprap the upstream face. In July 1956, the embankment was widened 5 to 8 feet along the upstream face using grinding grit fill from the company and road demolition fill provided by the City of Worcester. (Reports and correspondence describing these events are included in Appendix B). By August 1956, the vehicular bridge over the spillway had been removed, and the flashboards were removed at about the same time.

In 1958, a model study for the design of a spillway was completed by Professor Hooper at the Alden Hydraulic Laboratory at Worcester Polytechnic Institute. (A copy of that report and the proposed redesign of the spillway is given in Appendix D.) The new spillway was never constructed.

According to the Owner, additional filling and widening of the dam embankment with grinding grit from the Coes Knife Company continued from 1956 to until about 1975. After 1975, the grinding grit was disposed of offsite. There are no drawings or records that show the exact limits or extent of the filling.

1. Normal Operating Procedure. There are no normal operating procedures at the dam. The only outlet conduit was a 36-inch diameter iron pipe and a gate valve at Coes Knife Company. The conduit was cut off by sheet piling in 1936.

   The spillway for Coes Reservoir Dam is ungated and flows are unrestricted.

1.3 Pertinent Data

a. Drainage Area. The approximately 7,000-acre (10.9 square miles) drainage area above the dam includes the drainage areas of four other upstream reservoirs: Holden Reservoir No. 1 and No. 2, which are Worcester County water supply reservoirs; and Cook Pond and Patch Reservoir which are recreational ponds (see Watershed Plan, Figure D-1). The northern two-thirds of the drainage area, including the reservoir watersheds and the Cook Pond drainage area, is sparsely developed, heavily wooded, and has moderately steep slopes. The southern third of the drainage area, including Patch and Coes Reservoirs, is moderate to densely developed, partially wooded, and has gentle to moderately steep slopes.

   Discharge from Coes Reservoir is to Lower Coes Pond which has a dam 1,300 feet downstream. Water then joins Beaver Brook and flows south to Kettle Brook at Curtis Ponds Dam in Webster Square. This is a highly developed commercial area located 0.8 miles downstream of the Coes Reservoir Dam. Flow then continues east in Middle River and eventually to the Blackstone River below Quinsigamond Pond Dam.

b. Discharge. Normal discharge is over the ungated spillway. The spillway weir is 38.5 feet long and the crest is at El 501.0. Water flows down a 110 foot long, 38 foot wide, stone-lined channel which slopes steeply at 7:1. This channel has dry-stone

masonry side walls about 4 feet high. Water then flows from the channel downstream in the streambed and enters Lower Coes Pond about 200 feet downstream from the spillway crest.

The spillway can discharge an estimated 1,458 cfs at El 506.3 which is the low point on the dam crest. An inflow test flood of 10,000 cfs results in an adjusted outflow of 8,500 cfs with the water surface at El 509.7. This will overtop the Coes Reservoir Dam by a maximum of 3.4 feet. The spillway can discharge only 17 percent of the outflow before the dam is overtopped.

The maximum flood level at the dam is unknown. The dam was breached to a depth of 4 feet in the March 1936 flood, but was not overtopped. Also, the dam was not overtopped during the August 1955 storms. It is not known, however, what the reservoir elevation was prior to either storm or what effect the storage at upstream reservoirs had on discharge to the reservoir.

c. Elevation (feet above Mean Sea Level (MSL)). A benchmark elevation of 501.0 at the spillway crest was estimated from a U.S.G.S. topographical map.

(1) Top dam: 506.3 to 508.3

(2) Test flood pool: 509.7

(3) Design surcharge (original design): unknown

(4) Full flood control pool: Not Applicable (N/A)

(5) Recreation pool: 501.0

(6) Spillway crest (ungated): 501.0

(7) Upstream portal invert diversion tunnel: N/A

(8) Stream bed at centerline of dam: 486.5 at toe of discharge channel

(9) Maximum tailwater: None.

d. Reservoir

(1) Length of maximum pool: 3,500 feet

(2) Length of recreation pool: 3,500 feet

(3) Length of flood control pool: N/A

e. Storage (acre-feet)

(1) Test flood surcharge: 790 at El 509.7

(2) Top of dam: 1,400

(3) Flood control pool: N/A

(4) Recreation pool: 900 (Approximate)

(5) Spillway crest: 900

f. Reservoir Surface (acres)

*(1) Top dam: 91

*(2) Maximum pool: 91

(3) Flood-control pool: N/A

(4) Recreation pool: 91

(5) Spillway crest: 91

g. Dam

(1) Type: earthfill with grinding grit fill and street demolition fill

(2) Length: 700 feet

(3) Height: 0 to 20 feet

*Based on the assumption that the surface area will not significantly increase with changes in reservoir elevation from 501 to 506.3.

(4) Top width: 30 feet

(5) Side slopes: Upstream 1:1; downstream 3:1 to 5:1

(6) Zoning: Unknown

(7) Impervious core: Oak and brick sheeting with puddled trench

(8) Cutoff: Unknown

(9) Grout curtain: Unknown

i. Spillway

(1) Type: Broad crest

(2) Length of weir: 38.5 feet

(3) Crest elevation: 501.0 MSL (assumed benchmark)

(4) Gates: None

(5) Upstream Channel: Mortared masonry training walls

(6) Downstream Channel: 38-foot wide, 110-foot long discharge channel, slopes at 7:1 with 4-foot high side walls

(7) General: Tailrace channel from sealed outlet conduit enters spillway discharge channel 130 feet downstream of crest.

j. Regulating Outlets. There are no operable regulating outlets at this dam. An abandoned 36-inch diameter iron outlet conduit is located 130 feet south of the spillway and leads to a gate valve in Coes Knife Company. The conduit was sealed off with sheet piling in 1936, and the gate valve is inoperable.

SECTION 2

ENGINEERING DATA

2.1 General. There are no plans, specifications, or computations available from the Owner, State, or County offices on the design, construction, or repair of this dam. The Owner did provide a file of old correspondence, inspection reports, photographs, and property maps for review. (Copies of the pertinent information are included in Appendix B and Appendix D.) A hydraulic analysis and model study was conducted for the spillway at Coes Reservoir by Professor Hooper at the Alden Hydraulic Laboratory, Worcester Polytechnic Institute. A copy of the report was provided by the Owner (included in Appendix D).

A topographic survey of the spillway area was prepared in July 1956 by A. E. Raymond, an employee of the Coes Knife Company. Some information from that survey was used in the preparation of Figure B-1. The only other data available for this evaluation were visual observations during inspection, review of additional inspection reports, and conversations with personnel from the State and County agencies.

We acknowledge the assistance and cooperation of personnel of the Massachusetts Department of Public Works: Messrs. Willis Regan and Raymond Rochford, and of the Massachusetts Department of Environmental Quality Engineering, Division of Waterways: Messrs. John J. Hannon and Joseph Iagallo.

Also, we acknowledge the cooperation and assistance of personnel from the Worcester County Engineer's Office: Messrs. John O'Toole, Joseph Brazauskas, and Mr. Wallace Lindquist - recently retired from county service.

In addition, we thank Messrs. Jim Hillhouse, Joseph Lajuenesse, and Bud Higgins of the Coes Knife Company (Owner of the dam) who allowed us to inspect the dam and provided us with information on the history and past performance of the dam.

2.2 Construction Records. There are no detailed construction records available.

2.3 Operation Records. No operation records are available, and there is no daily record kept of pool elevation or rainfall at the dam site.

2.4 Evaluation.

a. Availability. Due to the age of this dam, available engineering data is limited.

b. Adequacy. The lack of in-depth engineering data did not allow for a definitive review. Therefore the adequacy of this dam could not be assessed from the standpoint of reviewing design and construction data, but is based primarily on visual inspection, past performance history and sound engineering judgment.

c. Validity. The limited data available is considered valid.

SECTION 3

VISUAL INSPECTION

3.1 Findings

a. General. The Phase I inspection of the dam at Coes Reservoir was performed on July 24, 1978. A copy of the inspection checklist is included in Appendix A. This dam has been inspected periodically by others since 1925. A partial listing of these inspections is in Appendix B. The most recent inspection was conducted on January 10, 1973 by representatives of the Massachusetts Department of Public Works. A copy of their report, selected earlier reports, and correspondence pertaining to the condition of the dam are included in Appendix B.

b. Dam. The original dam is an earthfill dam that has subsequently been filled with grinding grit and road demolition material. The grinding grit is a waste product from the Knife manufacturing operation and is composed of steel shavings and sand particles which appear to oxidize and form a hard outer surface. The only information on the zoning or core is a note on the partial listing of previous inspections (page B-2) stating that the core is made of oak and brick with a puddled trench.

Several signs of distress were observed, the most significant being erosion of the upstream face of the dam which is generally a 1:1 slope without riprap. In several places on the upstream face, the grinding grit is being undermined by wave erosion, causing local sloughing of the slope. The dam section just north of the spillway consists of sand which has been eroded. In this area, undercutting of the bank along the upstream edge of the crest has caused portions of a chain-link fence to fall.

There is significant growth of trees and brush on the dam embankment. The crest is fairly clear, but five large trees, 18 to 36

inches in diameter, are growing there. The upstream face has a moderate growth of brush, and the downstream face is heavily overgrown with brush and small trees. Seepage was observed entering the tailrace from around tree roots embedded in the upstream side wall of the channel.

c. Appurtenant Structures. The spillway is a broad-crested concrete slab weir with concrete-faced masonry side walls. Flow over the spillway is unrestricted. The downstream channel is steeply sloping at 7:1, lined with stone, and has dry-stone masonry side walls. There is a small concrete channel adjacent to the north wall of the channel.

The concrete on the spillway crest is cracked and eroded in places. Debris such as wood, stones, and trash is scattered on the crest. The stonework in the north training wall is loose and has fallen out of place. In the downstream channel, the concrete side channel is broken and tilted out of place, and sections of the south wall have collapsed. Seepage enters the concrete channel from the base of the north wall about 35 feet below the spillway crest. Trash and other debris is scattered on the floor of the channel. Dense vegetation occurs along both walls of the discharge channel and on the bottom of the channel along the north wall. The growth is mostly brush and small trees, but three large (12-inch to 36-inch diameter) trees are growing on the north side. One tree is near where seepage is flowing into the concrete side channel.

An abandoned intake consisting of a 36-inch diameter iron pipe leads into a gatehouse at Coes Knife Company. The top of the steel sheet piling that cuts off the pipe can be seen in the upstream face of the dam embankment. The control valve, located in the gatehouse at the toe of the dam is rusted and leaking slightly. A tailrace channel which used to carry discharge flow from the gatehouse is located under the Coes Knife Company

building and continues from the toe of the dam to about 130 feet downstream of the spillway. Seepage occurs at three points along the upstream wall of the channel, usually where tree roots are embedded in the stonework. The channel bottom contains some trash and other debris.

d. Reservoir Area. The reservoir area is densely populated and contains over 100 residences. The drainage area is about 75 percent wooded and 25 percent developed. Slopes range from about 5 to 20 percent.

e. Downstream Channel. Discharge from the spillway flows down a stone-lined channel which is 110 feet long and has a slope of 14 percent. Water then flows down a relatively flat, sandy streambed for a distance of about 100 feet and into Lower Coes Pond. The lower pond is about 1,100 feet long and is dammed at the downstream end near Park Avenue. Flow then moves south to Middle River at Webster Square and then east to the Blackstone River below Quinsigamond Pond Dam.

3.2 Evaluation. The above findings indicate that the dam has several signs of distress that require attention. It is evident that the dam has not been maintained and that deterioration will continue unless action is taken. Recommended measures to improve these conditions are stated in Section 7.3.

SECTION 4

OPERATION PROCEDURES

4.1 Procedures. There are no operational procedures at this dam.

4.2 Maintenance of Dam. The dam is not adequately maintained even though the Coes Knife Company is located immediately adjacent to and downstream of the dam. Recommendations made to Coes Knife Company in 1955 by the Worcester County Commissioners Office were that: the embankment needs flattening and filling, riprap is required on the upstream face, and trees and brush need to be cleared from the crest and downstream face of the dam. Also, the spillway needs repair at the north side wall, the concrete side channel in the discharge channel should be removed, and trees and brush should be cleared from the sides of the discharge channel. Further, it was recognized that the spillway was inadequate and should be enlarged. There was no evidence that this work was ever done.

The most recent maintenance activities (about 1956) have been the removal of the flashboards and vehicular bridge over the spillway. The only other change to the dam has been the continued enlargement of the embankment with grinding grit from 1956 to 1975.

4.3 Maintenance of Operating Facilities. The intake conduit to the wheel house has been sealed off since 1936. There are no other known or visible outlets from this pond.

4.4 Description of Any Warning Systems in Effect. There are no warning systems in effect at this dam.

4.5 Evaluation. There are no operational, maintenance, or warning systems in effect at Coes Reservoir Dam. This is extremely undesireable considering that the dam is in the "high" hazard category. A program of operation and maintenance should be implemented, as recommended in Section 7.3.

SECTION 5

HYDRAULIC/HYDROLOGIC

5.1 Evaluation of Features

a. Design Data. The total drainage area for Coes Reservoir is approximately 10.9 square miles. The reservoir receives flow from Patch Reservoir and 2 square miles of tributary area directly below Patch Reservoir. A Phase I investigation has already been completed for Patch Reservoir, (MA 00122). The inflow test flood is based on calculated discharge from Patch Reservoir plus an estimate of flow from the tributary area directly below Patch Reservoir. The Probable Maximum Flood (PMF) rate was determined to be 2,050 cfs per square mile for the drainage area below Patch Reservoir. This calculation is based on the average drainage area slope of 6 percent, the pond-plus-swamp area to drainage area ratio of 8.5 percent, and the U. S. Army Corps of Engineers' guide curves for Maximum Probable Flood Peak Flow Rates (dated December 1977). Applying one-half the PMF to the 2 square miles of drainage area results in a calculated peak flood flow of 2,050 cfs. The outflow from Patch Reservoir of 7,950 cfs plus the peak flood flow of 2,050 cfs results in a calculated inflow test flood of 10,000 cfs. By adjusting the inflow test flood for surcharge storage, the maximum discharge rate was established as 8,500 cfs (780 cfs per square mile), with a water surface at El 509.7.

Flow over the crest of the dam is computed to be 5,460 cfs, while flow through the spillway is 3,040 cfs. The maximum head on the dam would be 3.4 feet with a discharge of 15.6 cfs per foot of width. Depth at critical flow would be at 0.6 feet with a velocity of 8 feet per second.

Hydraulic analyses indicate that the existing spillway can discharge a flow of 1,458 cfs (only 17 percent of the outflow test flood) at water surface El 506.3, which is the crest of the dam.

The inflow from a 100-year-frequency storm was estimated to be 4,005 cfs. After adjustment for surcharge storage, the outflow from the 100-year storm was calculated to be 3,080 cfs which would result in a water surface at El 507.5 or about 1.2 feet over the dam.

b. Experience Data. Hydraulic records are not generally available for this dam, however, information supplied by the Owner indicates that the dam was nearly overtopped during the March 1936 floods. According to photographs and newspaper articles on the flood, the dam was breached in the right abutment area near Mill Street. Further information supplied by the Owner indicates that the dam was not overtopped during the 1955 floods either. However, the water level was observed at the crest of the dam during both the 1936 and 1955 floods.

The Owner has provided copies of previous hydraulic investigations at this site. This consists of a letter by Mr. Frederick J. Sanger, dated September 18, 1955, and a report entitled "Hydraulic Design for Coes Reservoir Spillway", by Alden Hydraulic Laboratory, dated December 1958. (Copies are included in Appendix D.) This information describes the analysis and model studies for the design of a proposed enlargement to the spillway at Coes Reservoir. A spillway discharge of 3,000 cfs was used to determine the hydraulic design for the spillway. The basis for this design discharge is discussed in the letter (page D-8). The results of this investigation were never implemented, as the spillway was never enlarged or modified.

c. Visual Observations. The spillway consists of a 38-foot long, broad-crested concrete weir with a steep stone-lined discharge channel. Water over the spillway discharges into Lower Coes Pond 200 feet downstream from the dam.

The spillway is ungated and flow is unrestricted. No flashboards were in place during the inspection. A metal sill imbedded in the

weir and keyways in the training walls of the spillway indicates that flashboards were used at one time. This was confirmed by previous inspection reports and discussions with the Owner.

d. Overtopping Potential. Overtopping of the dam is expected under the test flood of 10,000 cfs (inflow) as well as the 100-year-frequency flood. As noted previously, the only available records indicate that the dam was not overtopped during the 1936 and 1955 floods. Previous hydraulic investigations, as discussed above, indicate that the spillway is inadequate and should be widened. In the event of overtopping, complete failure of the dam could occur. A flood wave resulting from failure of the dam could cause appreciable property damage and numerous losses of life. Since the Coes Factory is located immediately downstream of the dam, calculation of the failure flood wave-height was not considered appropriate.

e. Additional Hydraulic Considerations. As shown in Figure D-1, Coes Reservoir is located downstream of Holden Reservoirs No. 1 and No. 2, Cook Pond, and Patch Reservoir. The calculations for a Phase I Investigation are based on the U. S. Army Corps of Engineers guide curves which do not totally consider the storage discharge characteristics of upstream reservoirs. The inflow test flood for Coes Reservoir, however, has included the storage effect of Cook Pond and Patch Reservoir but not of Holden Reservoirs No. 1 and No. 2. Therefore, the conclusions on peak flows and dam overtopping should be considered as preliminary only. A more detailed hydrologic and hydraulic investigation should be based on the storage effects of all upstream reservoirs.

SECTION 6

STRUCTURAL STABILITY

6.1 Evaluation of Structural Stability

a. Visual Observations. The evaluation of the structural stability of Coes Reservoir Dam is based on the visual inspection on July 24, 1978.

Based on the observations discussed in Section 3, Visual Inspection, Coes Reservoir may be a hazard. Conditions at the dam are unsatisfactory and conventional factors of safety may not exist.

It is recommended that a more detailed investigation be initiated to evaluate the stability of the dam and the seepage at the downstream masonry wall.

b. Design and Construction Data. Discussions with the Owner, County, and State personnel indicate that there are no plans, specifications, or computations relative to the design, construction, or repairs of this dam. Furthermore, information does not appear to exist on the type, shear strength, and permeability of the soil and/or rock materials of the embankment. Grinding grit fill and street demolition fill which comprise part of the embankment are presumably highly variable in composition, strength, and permeability.

It was learned that this dam was originally built in 1865, probably of local soil or rock materials. Available information indicates that the impervious core may consist of oak and brick sheeting with a puddled trench. The oak sheeting was probably bounded on each side by a brick wall. An impervious cutoff was probably used at this site, since the natural soils are relatively pervious. Timber core walls will generally last an

indefinite period, provided the timber is continuously saturated. In the event that the reservoir is substantially lowered for longer than three months, the timber may rot, causing the dam to leak.

The original earth embankment is no longer visible due to extensive filling of the slopes and crest with grinding grit from the Knife Company and with some fill from street demolition. The slopes are irregular, and it appears that the fill was randomly dumped without being graded or compacted.

c. Operating Records. There is no evidence that instrumentation of any type was ever installed in Coes Reservoir Dam. The performance of this dam under prior loading can only be inferred from physical evidence at the site.

d. Post-Construction Changes. There are no as-built drawings for Coes Reservoir Dam. Available records indicate that the embankment was raised in 1871 and 1872, and that 4 more feet were added in 1895. The intake conduit into Coes Knife Company was cut off with sheet piling in 1936 but is still in place. A vehicular bridge over the spillway and flashboards mounted on the crest were removed in about 1956. For about 20 years, from 1956 to 1975, the earth embankment was widened with fill, primarily grinding grit. Records indicate that at least 8 feet of width were added to some areas of the upstream face.

e. Seismic Stability. The dam is located in Seismic Zone No. 2 and in accordance with Phase I "Recommended Guidelines" does not warrant seismic analyses.

SECTION 7

ASSESSMENT, RECOMMENDATIONS, AND REMEDIAL MEASURES

7.1 Dam Assessment

a. Condition. Due to its age, Coes Reservoir Dam was neither designed nor constructed according to current approved state-of-art procedures. Based upon the visual inspection at the site, the lack of engineering data and limited evidence of operational or maintenance procedures, there are areas of concern which must be corrected to assure the continued performance of this dam. Generally, the dam is considered to be in fair condition. The following signs of distress were observed at the site: the steep upstream face of the dam is eroded and unprotected, the concrete weir and stone training walls in the spillway are deteriorated, the concrete side channel in the discharge channel is cracked and collapsing, water is seeping from the upstream wall of the tailrace and from the north wall of the discharge channel, and there is a dense growth of brush and trees on the embankment of the dam and in downstream areas.

Hydraulic analyses indicate that the existing spillway can discharge a flow of 1,458 cfs (17 percent of the test outflow) at El 506.3 which is a low point on the dam crest. An inflow test flood of 10,000 cfs will overtop the main dam by about 3.4 feet. Previous records indicate that the dam was not overtopped by the floods of 1936 or 1955; however, the dam was breached 4 feet deep near the south abutment (Mill Street) during the 1936 flood. There is no available information on the pond levels prior to the storms. The 1955 storm occurred in August when the upstream reservoirs would generally be low, which may explain why the dam was not overtopped, even though the 1955 storm was more severe than the one in 1936. Hydraulic

studies published in 1958 also state that the dam is susceptible to overtopping with the present spillway capacity. It is likely that overtopping is a serious potential hazard which could cause a high loss of life and property damage. Further development on the watershed may increase this hazard in the future.

b. Adequacy of Information. The lack of indepth engineering data dis not allow for a definitive review. Therefore the adequacy of this dam could not be assessed from the standpoint of reviewing design and construction data, but is based primarily on visual inspection, past performance history and sound engineering judgment.

c. Urgency. The recommendations outlined below should be implemented within 1 or 2 years after receipt of the Phase I Inspection Report.

d. Need for Additional Information. Additional investigations to further assess the adequacy of the dam and appurtenant structures are outlined below in Section 7.2 Recommendations.

7.2 Recommendations. In view of the concerns about the continued performance of this dam, it is recommended that the Owner employ a qualified consultant to:

a. evaluate the stability of the dam and the seepage along the upstream wall of the tailrace channel; and

b. conduct a more detailed hydraulic and hydrologic investigation for the entire drainage area. The purpose of the investigation is to design a new spillway to discharge a greater portion of the test flood and a new outlet facility for dewatering the reservoir.

The recommendations on repairs and maintenance procedures are stated below under Section 7.3, Remedial Measures.

storms. All repairs and maintenance should be undertaken in accordance with all applicable State regulations.

APPENDIX A

PERIODIC INSPECTION CHECKLIST

PERIODIC INSPECTION

PARTY ORGANIZATION

PROJECT Coes Reservoir

DATE July 24, 1978

TIME 8:00AM - 12:00

WEATHER partly sunny [illegible]5°

W.S. ELEV. [illegible]01* U.S. ____ DN.S.

*assumed benchmark [illegible]

PARTY:

1. Ed Greco	6. Lyle Branagan
2. Dick Weber	7. Carol S[illegible]
3. Sue Pierce	8.
4. Frank Sviokla	9.
5. David Cole	10.

	PROJECT FEATURE	INSPECTED BY	REMARKS
1.	dam embankment	Ed Greco / Dick Weber	
2.	Spillway	Lyle Branagan	
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			

PERIODIC INSPECTION CHECK LIST

PROJECT Coes Reservoir DATE July 21, 1973

PROJECT FEATURE dam embankment NAME Ed Green

DISCIPLINE geotechnical NAME Dick Weiss

AREA EVALUATED	CONDITIONS
DAM EMBANKMENT Crest Elevation	earth dam subsequently filled with grinding grit - varies from 506.2 to 508.3
Current Pool Elevation	501
Maximum Impoundment to Date	unknown
Surface Cracks	none visible
Pavement Condition	parking area near Mill St. - [illegible]
Movement or Settlement of Crest	none visible
Lateral Movement	[illegible] slope, due to filling
Vertical Alignment	slightly irregular
Horizontal Alignment	highly irregular
Condition at Abutment and at Concrete Structures	west abutment ties into Mill St; east abutment into natural hillside; no spillway abutment is beach-sand eroded + fence posts undercut, training wall stones loose + out of place; so. spillway abutment is grinding grit fill
* Indications of Movement of Structural Items on Slopes	filling on downstream + upstream slopes Knife company located directly downstream
Trespassing on Slopes	chipmunks, fishermen, swimmers
Sloughing or Erosion of Slopes or Abutments	significant erosion on us face - no riprap; 5 trees (18"-36" dia) + brush on us face - dense brush on ds face; erosion beneath conc. slab on ds face adjacent to Knife co.
Rock Slope Protection - Riprap Failures	no rip rap
Unusual Movement or Cracking at or near Toes	none visible
Unusual Embankment or Downstream Seepage	water flowing along toe non build no apparent seepage from embankment
Piping or Boils	none
Foundation Drainage Features	none
Toe Drains	none
Instrumentation System	none

* concrete headwall on us face 100' NO. of spillway - 50'Lx 4'hx 1.5' thick (old foundation ?)

PERIODIC INSPECTION CHECK LIST

PROJECT Coes Reservoir DATE July 24, 1973

PROJECT FEATURE spillway NAME Ed Gross

DISCIPLINE geotechnical NAME Lyle Brazeau

AREA EVALUATED	CONDITION
OUTLET WORKS - SPILLWAY WEIR, APPROACH AND DISCHARGE CHANNELS a. Approach Channel	bottom- natural sandy gravel east abutment- loose pcs. stone west abutment- natural slope + dumped stone
General Condition	fair.
Loose Rock Overhanging Channel	none
Trees Overhanging Channel	none
Floor of Approach Channel	natural sandy gravel
b. Weir and Training Walls	weir is concrete slab - 4 I-beams for former bridge walls concrete facing on stone masonry (±1 ft thick)
General Condition of Concrete	walls-fair; weir-poor, cracked + local erosion scattered debris (wood, rocks, trash) on weir
Rust or Staining	12" metal sill on us edge of weir- slides in training walls - former frame for flashboards
Spalling	none visible
Any Visible Reinforcing	none visible
Any Seepage or Efflorescence	none
Drain Holes	none
c. Discharge Channel **	sloping stone-lined channel w/dry stone masonry sidewalls; conc. side channel along no. wall
General Condition	channel + walls - fair; concrete side channel - v. poor, cracked + broken, weed + brush growth, seepage at ⅓ ds from base of north side wall
Loose Rock Overhanging Channel	dry-stone masonry wall at downstream end of channel on north slope
Trees Overhanging Channel	36", 18", 12" trees on north side - one is opposite seepage @ base of wall; small trees on south side
Floor of Channel	scattered debris, some vegetation, fallen sections of concrete side channel
Other Obstructions *	18" dia. metal drain pipe discharging at ds end, north side of channel, near stone wall

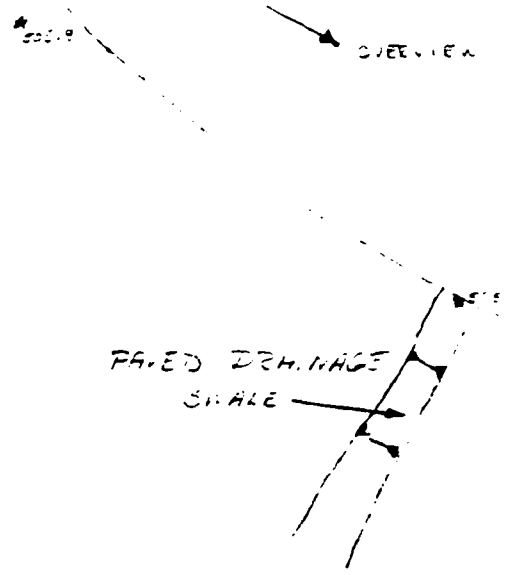
*tailrace channel- dry-stone masonry side walls, arch outlet opening, discharges at downstream end of sloped channel - 3 seeps on us wall near tree roots, some debris in channel bottom

**stream to Lower Coes- heavily overgrown, west bank- slag fill, east bank- stone retaining wall to Lakeside Avenue

APPENDIX B

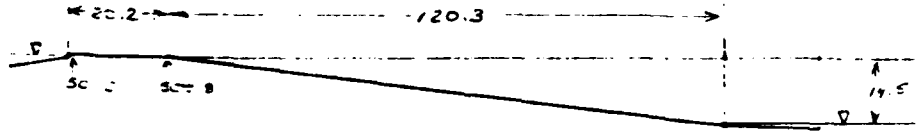
PLAN OF DAM AND PREVIOUS
INSPECTION REPORTS

	Page
Figure B-1. Plan of Dam, and Sections	B-1
Previous Inspections (Partial Listing)	B-2
Inspection Report by Mass. Department of Public Works, January 1973	B-4
Letter by Coes Knife Company	B-10
Letter by Worcester County Commissioners, May 1956	B-11
Inspection by Worcester County Commissioners, March 1956	B-13
Inspection by Worcester County Commissioners, September 1955	B-14

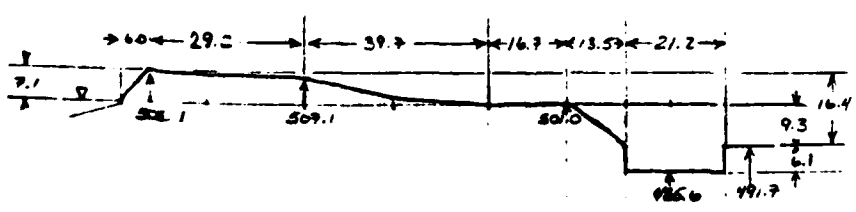


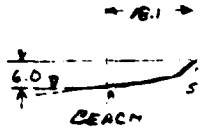
NOTES:

1. ELEVATIONS SHOWN ARE REFERENCED TO ASSUMED BENCHMARK ELEV. 50.0 (MSL) ON SPILLWAY CREST.
2. INFORMATION SHOWN BASED ON FIELD SURVEY OF JULY 24, 1978, AND TOPOGRAPHIC MAP OF SPILLWAY BY A.E. RAYMOND, JULY, 1956
3. ▲ DENOTES SEEPAGE
4. #2 → SIGHTS VIEW OF PHOTOGRAPHS



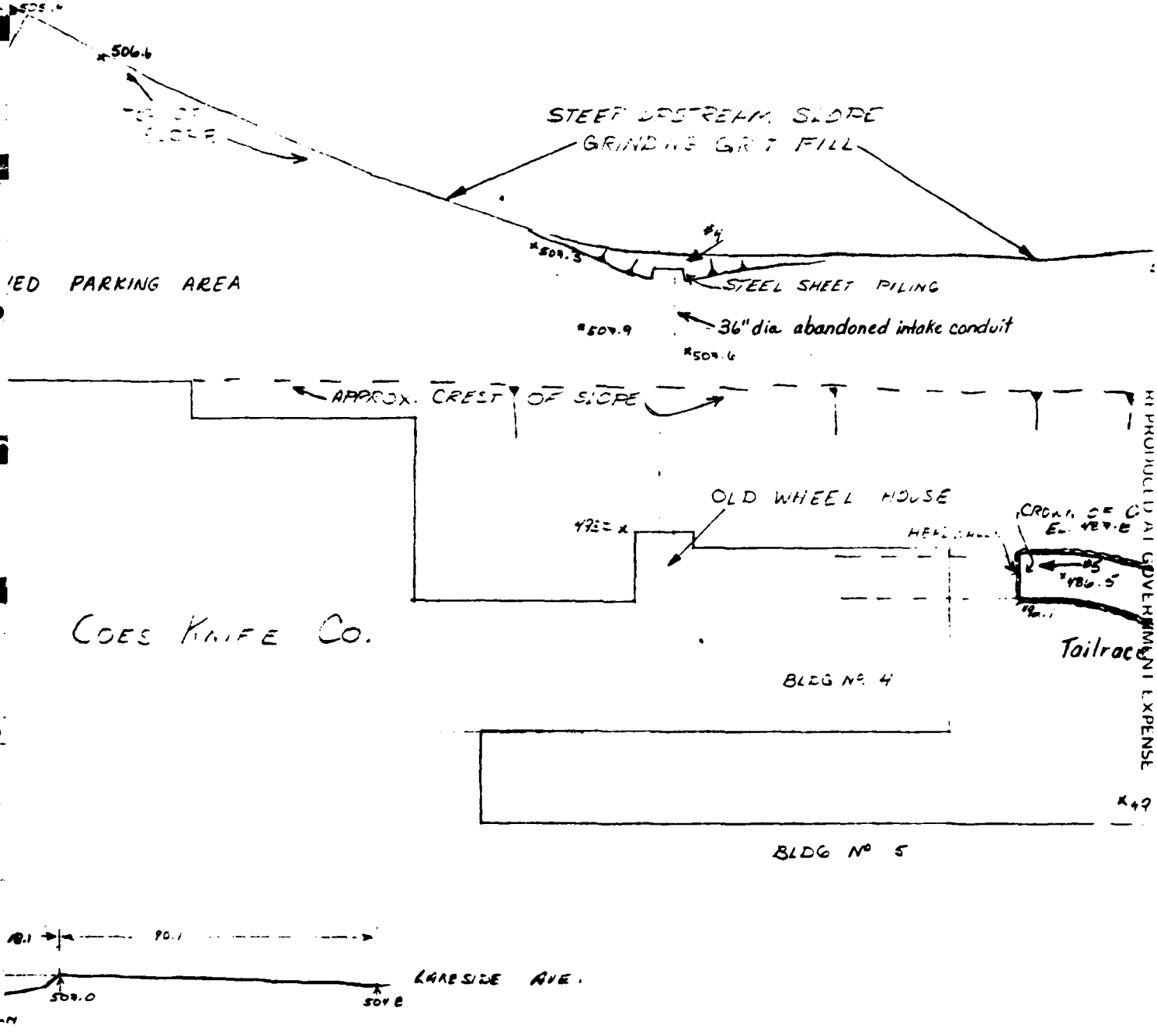
SECTION 2-2





SECTION 1-1

METCALF & EDDY INC.



SECTION 3-3.

2

3

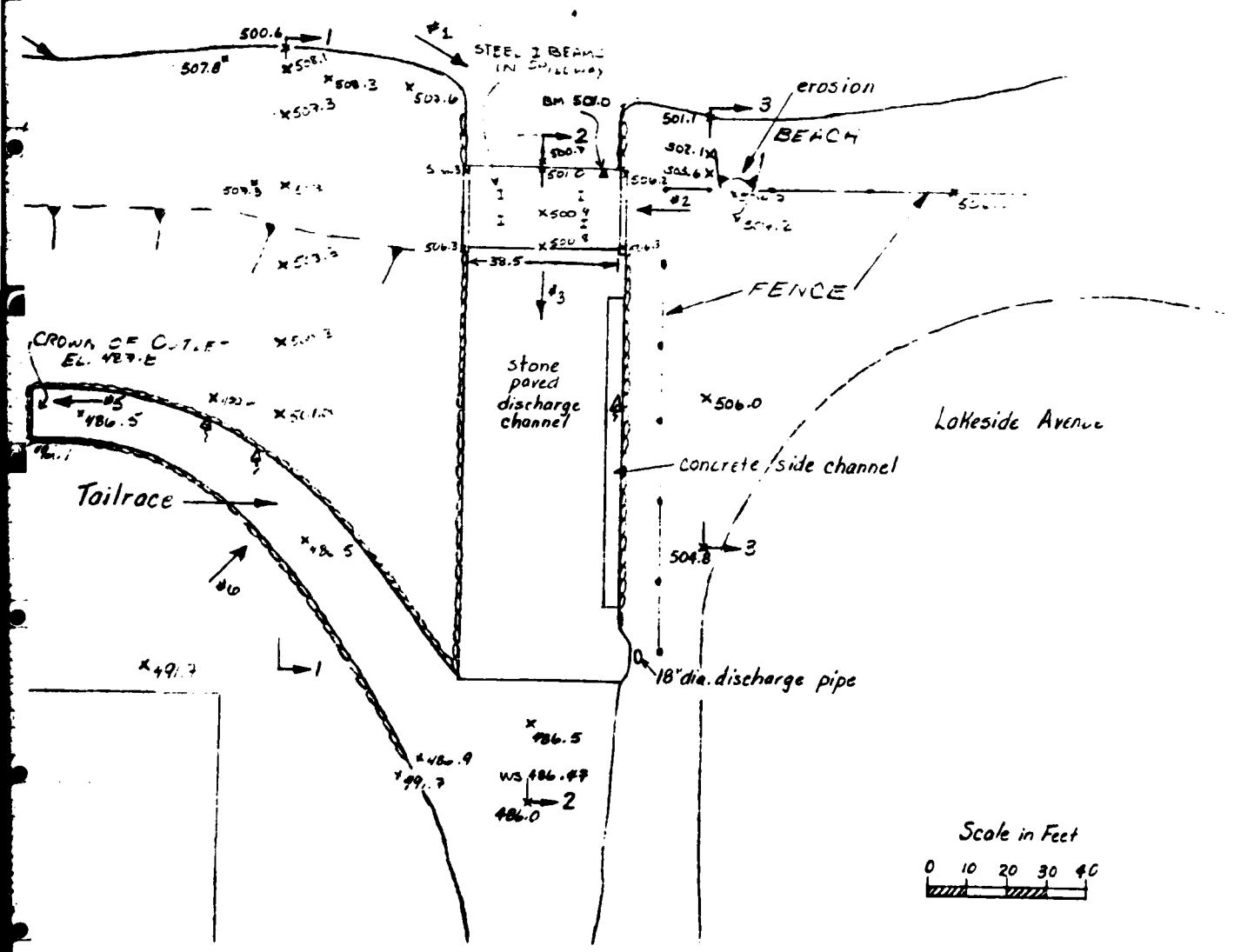


FIGURE B-3 PLAN OF DAM AND SPILLWAY

TOWN OR CITY Worcester DECREE NO. PLAN NO. DAM NO. (1) 348 - 03

LOCATION Coes Reservoir - Will St. - upper C. C. DOCKET NO.

DESCRIPTION OF DAM

Type 3 Oak Sheeting - puddled trench - Apron - Abts = Stone, Stepped {Stone, Concrete}
Length 400'±
Height Top. Spill. 12. Flash. 14. Emb. 18'
Thickness top 24'
" bottom prob. 60-70
Downstream Slope
Upstream " rip rap.
Length of Spillway El. crest = 940 30 ft.
Size of Gates Waste - 30"ø also Draft - 30" El. 82.5
Location of Gates waste closed by Steel Sheeting - 1936
Flashboards used El. Crest of Spillway 5.0'3 Yes
Width Flashboards or Gates El. 96.0 24"
Dam designed by Loring Coes.
" constructed by
Year constructed 1864 - 1865 - 1866 - 1867

GENERAL REMARKS 1937 - Owned by Coes Wrench Co - owners

Inspected Sept. 10, 1925 - L.O. Marden
" Aug. 15, 1927 - " "
" July 6, 1929 - " "
" Dec. 17 1931 - " "
" April 25 1932 - " " Tinsley, Holland, Barton and Underwood.
" " 26 "
" " 11, 1933 - " "
" " 18 1933 " " ← Owned by Loring Coes Co

DESCRIPTION OF RESERVOIR & WATERSHED

Name of Main Stream Tatnuck brook
" " any other Streams
Length of Watershed 1955 - Coes Knife Co
Width " " 72. Coes St. Worcester.
Is Watershed Cultivated
Percent In Forests
Steepness of Slope trace
Kind of Soil
No. of Acres In Watershed 1957 - New size spill
" " " " Reservoir 118. to be 60'x6'
Length of Reservoir - Max Flow 3,200 cfps
Width " " design figure
Max Flow Cu. Ft per Sec.
Head or Flashboards-Low Water
" " " -High "

GENERAL REMARKS

Level of Pond fixed by Bench Mark of Copper placed in face of stone in foundation of #3. Shop.
Inspected: Dec. 29, 1936 - K. M. Finlayson
Inspected: Mar. 19, 1936 - L.O.M., G.W. Jones
" Mar. 18, 1936 - " G.W. Jones
Waste gate closed by Sheet piling 1936 by Coes Co
1936 Flood El. 307.3 [County Eng. not consulted]
Prof. Allen of Worc. Tech. E.J.
Loring Coes Co (over)

B-2

PREVIOUS INSPECTIONS (PARTIAL LISTING)

COPY OF INSPECTION CARD ON FILE AT THE MASSACHUSETTS DEPARTMENT OF PUBLIC WORKS, DISTRICT OFFICE, WORCESTER.

61-08

Inspected: June 23, 1937 - L.O.M. & E.M. Crockett
" : Nov. 17, 1938 - L. H. Spofford - Inspected: Sept. 21, 1938 - B.P. St. John
" : Jan 6, 1939 - J.C. Powers - Patrol
Patrol : Mar. 6 " B.P. St. John. Measured 3-1-39 by E.S. Grover - D.F. Doyle
Measured spillway Oct. 5, 1938 - B. P. St. John - E.S. Grover.
Inspected Dec. 9, 1940 - L. H. Spofford
" Dec. 7, 1942 - L.O.M. - J.F.C.
" April 5, 1945 - L.O.M. + L.H.S.
" Dec. 11, 1945 - W.O. Lindquist
" Nov. 13, 1947 - L.O.M. - Coes - Park Com.
" March 6, 1950 "
" March 6, 1951 - "

PREVIOUS INSPECTIONS (PARTIAL LISTING)

COPY OF INSPECTION CARD ON FILE AT THE MASSACHUSETTS DEPARTMENT OF PUBLIC WORKS, DISTRICT OFFICE, WORCESTER.

INSPECTION REPORT - DAMS AND RESERVOIRS

1. Location: City/Town WORCESTER Dam No. 3-14-348-08

Name of Dam COES RESERV DAM Inspected by [illegible]

Date of Inspection 1-10-73

2. Owner/s: per: Assessors _____ Prev. Inspection ✓

Reg. of Deeds _____ Pers. Contact _____

	Name	St. & No.	City/Town	State	Tel. No.
1.	COES KNIFE CO	72 COES ST	WORCESTER	MASS	
2.					
3.					

3. Caretaker (if any) e.g. superintendant, plant manager, appointed by absentee owner, appointed by multi owners.

Name: St. & No.

City/Town: State: Tel. No.

4. No. of Pictures taken NONE

5. Degree of Hazard: (if dam should fail completely)*

1. Minor _____ 2. Moderate ✓

3. Severe _____ 4. Disastrous _____

*This rating may change as land use changes (future development)

6. Outlet Control: Automatic _____ Manual _____

Operative _____ Yes; _____ No.

Comments: NONE

7. Upstream Face of Dam: Condition:

1. Good _____ 2. Minor Repairs ✓

3. Major Repairs ___ 4. Urgent Repairs _____

Comments:

8. Downstream Face of Dam:

Condition: 1. Good _____ 2. Minor Repairs ✓

3. Major Repairs _____ 4. Urgent Repairs _____

Comments:

9. Emergency Spillway:

Condition: 1. Good _____ 2. Minor Repairs _____

3. Major Repairs ✓ 4. Urgent Repairs _____

Comments: LOWER SECTION OF EMERGENCY SPILLWAY APRON HAS DETERIORATED AND LOWER SECTION OF WALL HAS FAILED

10. Water Level at time of inspection: 6 ft. above ___ below ✓

top of dam _____ principal spillway _____

other _____

11. Summary of Deficiencies Noted:

Growth (Trees and Brush) on Embankment YES

Animal Burrows and Washouts NONE

Damage to slopes or top of dam NONE

Cracked or Damaged Masonry EMERGENCY SPILLWAY

Evidence of Seepage NONE

Evidence of Piping NONE

Erosion NONE

Leaks NONE

Trash and/or debis impeding flow NONE

Clogged or blocked spillway NONE

Other _____

12. Remarks & Recommendations: (Fully Explain)

THERE IS SOME BRUSH GROWING ON UPSTEAM EMBANKMENT THAT SHOULD BE REMOVED, BUT OF MORE IMPORTANCE IS GROWTH OF TREES ON LOWER EMBANKMENT AND GROWING AMIDST CHANNEL PAVING BELOW THE MAIN PORTION OF THE DAM ITSELF. THE TREES UPON FALLING INTO THE STREAM COULD IMPEDE THE FLOW OF WATER AND MAY EVEN CAUSE ERODING OF DOWNSTREAM SLOPES. THE WALLS OF THE EMERGENCY SPILLWAY ((2) 8' SECTIONS) HAVE COLLAPSED, THE SPILLWAY (EMERGENCY) HAS BEEN UNDERMINED IN SOME AREAS. AS OF NOW THE EMERGENCY SPILLWAY SERVES NO PURPOSE IN THIS CONDITION. THE DAM PROPER INCLUDING SPILLWAY IS IN GOOD CONDITION AND SHOULD REMAIN FUNCTIONAL FOR SOME TIME TO COME

13. Overall Condition:

1. Safe ✓
2. Minor repairs needed ✓
3. Conditionally safe - major repairs needed _____
4. Unsafe _____
5. Reservoir impoundment no longer exists (explain)

   Recommend removal from inspection list _____

DESCRIPTION OF DAM

DISTRICT 3

Submitted by E. Metcalf

Date 1-10-73

Dam No. 14-348-08

City/Town Worcester

Name of Dam COES RESERVOIR DAM

1. Location: Topo Sheet No. 20 D

Provide 8½" x 11" in clear copy of topo map with location of Dam clearly indicated.

2. Year built: _____ Year/s of subsequent repairs _____

3. Purpose of Dam: Water Supply _____ Recreational ✓

Irrigation _____ Other _____

4. Drainage Area: 11.6 sq. mi. _____ acres

5. Normal Ponding Area: 100 ± acres; Ave. depth _____

Impoundments: _____ gals; _____ acre ft.

6. No. and type of dwellings located adjacent to pond or reservoir

5 BRICK APART BLDGS i.e. summer homes, etc. _____

7. Dimensions of Dam: Length 290'± Max. Height ✓

Slopes: Upstream Face 2 '

Downstream Face ½ : 1

Width across top 40'-45'

8. Classification of Dam by Material:

Earth ✓ Conc. Masonry ✓ Stone Masonry _____

Timber _____ Rockfill _____ Other _____

9. A. Description of present land usage downstream of dam:

_____ % rural; 100 % urban.

B. Is there a storage area or flood plain downstream of dam which could accomodate the impoundment in the event of a complete dam failure? yes ✓ no _____.

DAM NO. 3-14-348-08

10. Risk to life and property in event of complete failure.

No. of people 50.

No. of homes 10.

No. of Businesses 4.

No. of industries _____. Type _____

No. of utilities NONE. Type _____

Railroads NONE.

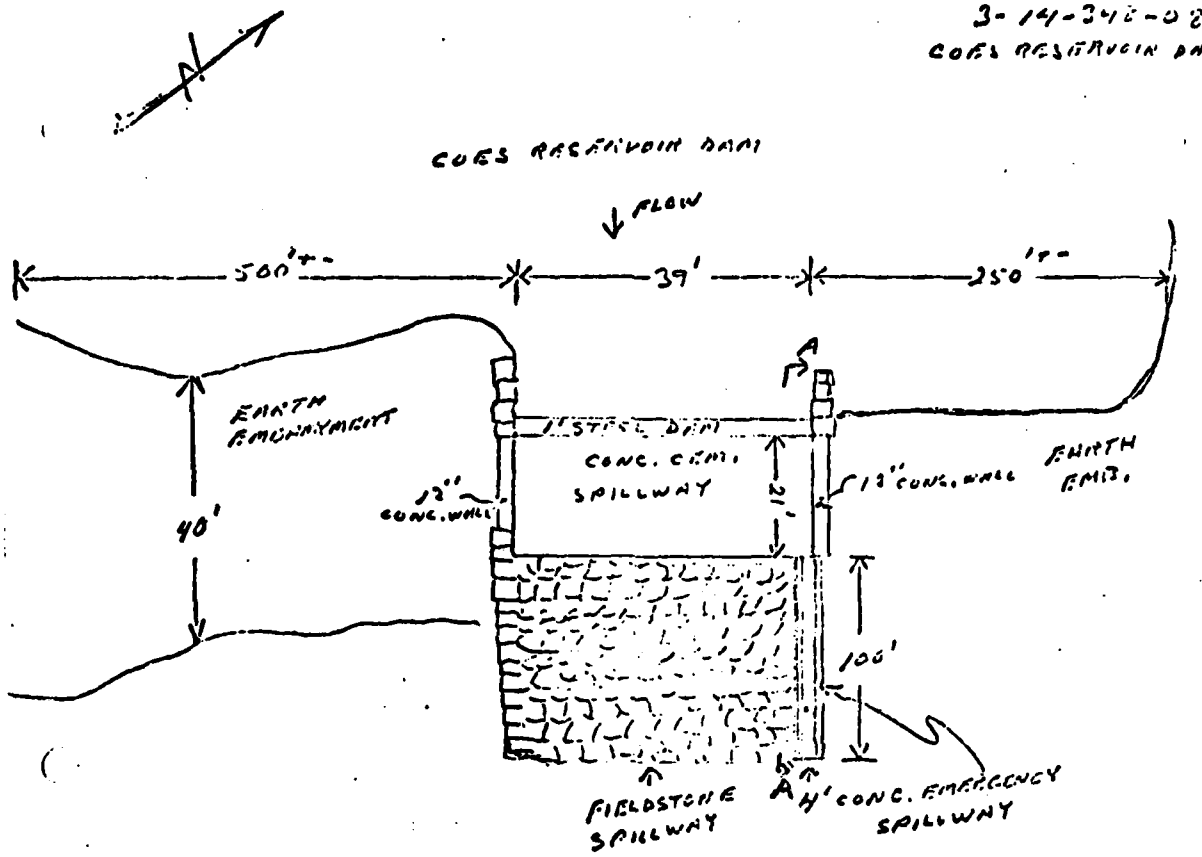
Other dams LOWER COES POND DAM

Other _____.

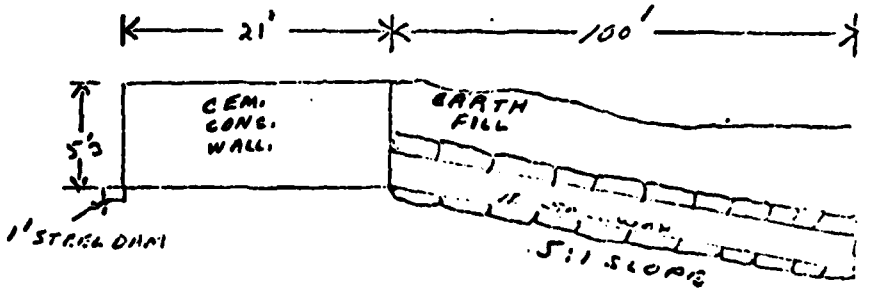
11. Attach Sketch of dam to this form showing section and plan on 6½" x 11" sheet.

12. How To Locate: PARK AVE TO COES ST. ENTER PARKING LOT AT 72 COES ST PROCEED TO UPPER PARKING AREA [illegible] OF PARKING LOT

WORCESTER
3-14-342-02
COES RESERVOIR DAM



SECT. A-A



Mr. Alexander B. Campbell
P.O. Box 57
Sagamore Beach, Massachusetts

July 11, 1956

Dear Mr. Campbell:

Following our telephone conversation this morning, George Collins and I reviewed the filling which had been accomplished on the dam.

First, you will recall, that we got quite a bit of fill from the housing development several years ago and this fill has formed a shelf for the new fill we have obtained recently. Starting from the Mill Street side we have dumped grinding muck of our own to build out an average of 8' (eight feet) from where the banking was last August at the time of the flood. This grinding muck fill extends over to a point in back of the Boiler Room. Then several loads from Vendetti and the City were dumped at the forge end of the Boiler Room, extending out about 8' (eight feet). Approximately 25 loads were dumped starting behind the Forge Room over to about 12' (twelve feet) beyond the old wheel house entrance building out the dam about 5 to 6 feet. All of this fill was from the City when they resurfaced Maywood Street from Park Avenue to Main Street. At that time they removed the 3' gutters from either side of Maywood Street and black-topped all the way to the curb.

Mr. Donohue has promised George Collins that they are going to do the same thing on May Street soon and we will get more fill at that time.

There are still several depression areas along in front of the old shipping dock and the next fill we get will be dumped in this area which extends for about 75'.

While dictating this, I decided it might be a good idea to have Jim Hillhouse go over this with George and make a small sketch which will probably make it clearer to you.

Very truly yours,
COES KNIFE COMPANY

Edwin E. Bloom
Executive Vice President

EEB/bm
Sketch

COMMONWEALTH OF MASSACHUSETTS
Worcester County Commissioners
COURT HOUSE, WORCESTER, MASSACHUSETTS
TELEPHONE PLEASANT 6-2441

JOSEPH A. ASPERO, WORCESTER, CHAIRMAN
FRANCIS E. CASSIDY, WEBSTER
EDWARD P. BIRD, FITCHBURG

May 18, 1956

Mr. Alexander B. Campbell, President
Coes Knife Company
72 Coes Street
Worcester, Massachusetts

Re: Your Dam - Coes Reservoir - County #61-08
Worcester, Massachusetts

Dear Sir:

I refer you to our letter of March 26, 1956 regarding our request for plans and specifications for a new spillway capable of handling rare flood flows to be submitted to the Board of County Commissioners at a date which would permit the reconstruction to be completed this summer.

Prof. L. J. Hooper, of the Alden Hydraulic Laboratory, in Holden, computed the new length and depth of this spillway which can safely carry the waters of a rare flood.

It will also be necessary for this plan to provide a draw off gate with pipe through the embankment at a location adjacent to the southerly abutment of the spillway.

You stated in your letter of April 12, 1956 to this Board that "When plans and specifications are prepared they will be submitted to the County Commissioners." This statement gives us no indication of the date these plans will be ready.

You also stated that you had just talked to City Manager, Francis J. McGrath, and that he has made a request for funds to do this work from the State Authorities, and he was awaiting a reply to his request.

The City of Worcester Sub-Flood Committee, of which our Engineer, Mr. L. C. Harden was a member, considers this dam to be the outstanding flood hazard in Worcester at the present time due to the inadequate size of the spillway.

If this Board cannot be supplied new plans and specifications drawn by a competent hydraulic Engineer by June 15, 1956 it will be necessary for us to issue an ORDER to you in writing in accordance with General Laws (Cor. Ed.) Chapter 253 and amendments thereto to provide such plans and specifications for the approval of the Board of County Commissioners.

Very truly yours,

WORCESTER COUNTY COMMISSIONERS

Joseph A. Aspero, Chairman

Francis L. Cassidy

Edward P. Bird

E:es

COMMONWEALTH OF MASSACHUSETTS
Worcester County Commissioners
COURT HOUSE, WORCESTER, MASSACHUSETTS
TELEPHONE PLEASANT 6-2441

JOSEPH A. ASPERO, WORCESTER, CHAIRMAN
FRANCIS E. CASSIDY, WEBSTER
EDWARD P. BIRD, FITCHBURG

Mail to
Alex Campbell
10 Tremont St.

March 26, 1956

Mr. Alexander Campbell, President
Coes Knife Company
72 Coes Street
Worcester, Massachusetts

Dear Sir:

Dam No. 61-08 - Coes Reservoir, Worcester, Mass.

An inspection of your dam last year showed the following repairs to be necessary:

1. Spillway.

   a. Stone abutment in poor condition on pond side.
   b. Steel channels and walkway I beams must be removed to give unobstructed flow of water over the spillway.

2. Embankment.

   a. Partly washed out both sides of spillway.
   b. Upstream slopes should be riprapped on pond side.

3. Gates.

   a. None visible.

4. At your meeting at the Court House with the County Commissioners, the necessity of constructing a wider and deeper spillway was discussed.

5. Plans and specifications for the new spillway should be prepared and submitted to the County Commissioners for their approval so that reconstruction can be completed this summer.

Very truly yours,

WORCESTER COUNTY COMMISSIONERS

Joseph A. Aspero

Joseph A. Aspero, Chairman

LOK/ja

COMMONWEALTH OF MASSACHUSETTS
Worcester County Commissioners
COURT HOUSE, WORCESTER, MASSACHUSETTS
TELEPHONE WORCESTER 6-2441

JOSEPH A. ASPERO, WORCESTER, CHAIRMAN
FRANCIS E. CASSIDY, WEBSTER
EDWARD P. BIRD, FITCHBURG

September 16, 1955

Coes Knife Company
72 Coes Street
Worcester, Mass.

Attention: Mr. Loring Coes

Dear Mr. Coes:

Subject: Inspection of Dam No. 61-07, Coes Square, Worcester, Massachusetts.

An inspection was made of this dam on September 12, 1955. We found that the condition of the dam was poor. The following repairs should be made:

SPILLWAY.

1. Two feet of flashboards in the two center sections of the spillway must be removed.
2. The stone abutment wall on the northerly end is in poor condition and should be rebuilt.
3. A new steel walkway will be required if any more stanchion boards are to be used on the crest of the spillway.

EMBANKMENT.

1. The embankment at the northerly end of the dam has been partly washed out.
2. A material composed of clay and loam must be used to replace the washed out portion.
3. The upstream slope of the embankment must be paved with stones eighteen inches in depth.

GATES.

1. It is apparent that water is leaking into the old penstock which has been blocked off.
2. At present the pond cannot be drained.
3. The present penstock should be replaced with a thirty-six inch steel pipe with a gate at the upper end and the lower end emptying into the stream channel.

Dam No. 61-07, Coes Square, Worcester, Cont'd.

Any structural changes to this dam must be in accordance with new plans submitted to the County Commissioners for their approval.

It is evident that this spillway is too small to handle a hurricane flow of water. The spillway should be lowered at least eighteen inches so as to give it additional capacity.

Attached are lists of instructions for the preparation and are of Reservoir or Mill Dams during the coming winter.

Very truly yours,

WORCESTER COUNTY COMMISSIONERS

By: Joseph A. Aspero, Chairman

LOM/ja
Enc.

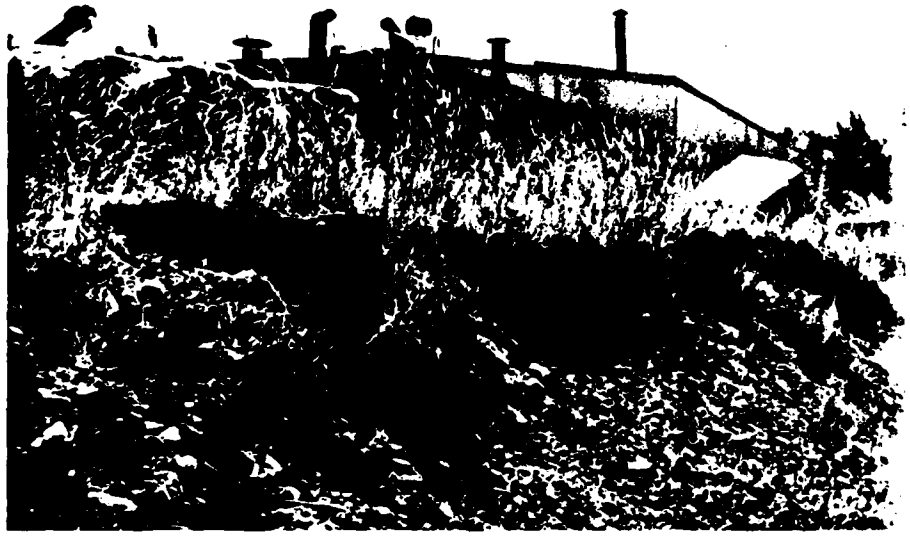
APPENDIX C

PHOTOGRAPHS

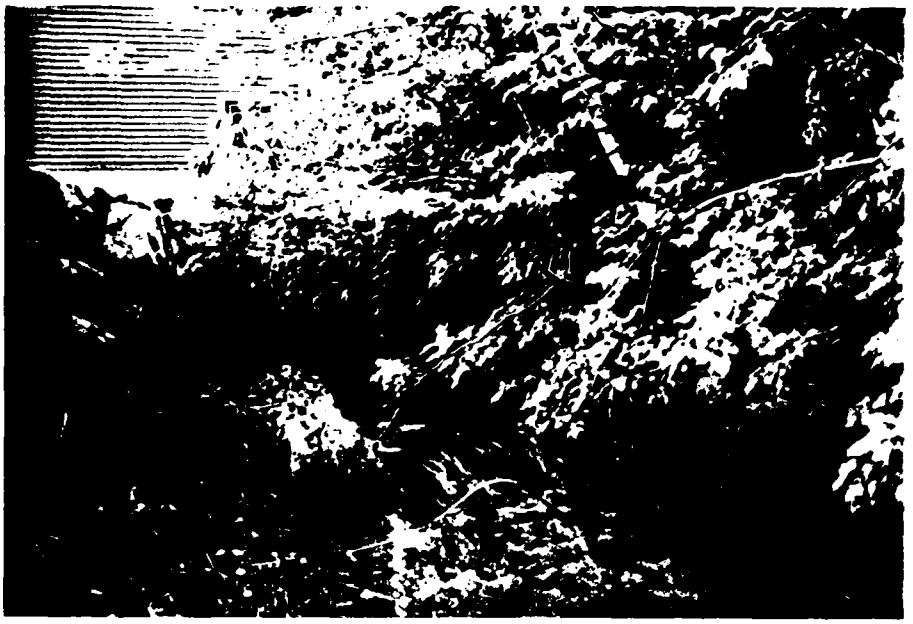
NO. 1 VIEW OF SPILLWAY CREST AND NORTH ABUTMENT

NO. 2 VIEW OF SPILLWAY CREST AND DAM EMBANKMENT

NO. 3 VIEW OF SPILLWAY CHANNEL



NO. 4 VIEW OF UPSTREAM FACE OF DAM



NO. 5 VIEW OF TAILRACE OUTLET AND CHANNEL

NO. 6 VIEW OF SEEPAGE FROM WEST WALL
OF TAILRACE CHANNEL

APPENDIX D

HYDROLOGIC AND HYDRAULIC COMPUTATIONS

	Page
Hydrologic and Hydraulic Computations	D-1
Watershed Plan, Figure D-1	In pocket
Letter from Frederick J. Sanger	D-8
Hydraulic Report by L. J. Hooper	D-11

Project Nat. Review of Non Fed. Dams Acct. No. 5864 Page 1 of
Subject Worcester Mass Area Comptd By LEB Date 7/24/78
Detail COES RESERVOIR DAM Ck'd By [illegible] Date [illegible]

(I) Inflow Test Flood & 100 Year Flood

Coes Res. recieves flow from Patch Res. plus 2.0 sq. miles of directly tributary area. Flood values will be based on previously calc. discharges from Patch, plus an estimate of peak flow from direct. trib. area. (D.T.A.)

A- D.T.A. - Ave. Slope $\cdot \frac{925-508}{7200} = 5.8\%$ - Say 6%

% Ponds & Swamps $= \frac{0.15 + .01 + .01}{2.0} = 8.5\%$

Peak Flow Rate slightly below "Rolling" - Say 2050 c.f.s /mi^2

B- Inflow Test Flood (for low dams @ ½ PMP)

D.T.A. $= 2050 \left(\frac{1}{2}\right) 2 =$ 2050 c.f.s.
From Patch 7950 "
Inflow Test Flood = 10000 c.f.s

C- 100 Year Flood
Say 4.7 inch rain in 6 hours @ 0.18 in/hr. infilt. (Type B S.C.S.)

D.T.A. $= 4100\left(\frac{4.7-1.1}{19-1.1}\right) =$ 825 cfs
From Patch 3180 "
100 Year Flood Inflow 4005 cfs.

(II) Storage Functions

Based on: Final $Q_{out} = Q_{in}\left(1 - \frac{S_F}{R}\right)$; S_F = Final Storage (in. on watershed)
R = Appl. 6 hr. rain

A - Test Flood: $Q_{out} = 10000\left(1 - \frac{S}{9.5}\right) = 10000 - 1052.6\,S = F_{TF}$

B - 100 Yr. Flood: $Q_{out} = 4005\left(1 - \frac{S}{4.7}\right) = 4005 - 852.1\,S = F_{100}$

METCALF & EDDY, ENGINEERS

Project Nat Review of Non-F. Dams Acct. No. 5864 Page 2 of
Subject Worcester, Ma. Area Compt'd By LEB Date 6/6/78
Detail COES RESERVOIR DAM Ck'd. By EM Date 5/2/
[Gen. Reference: "Open Channel Hydraulics" - Ven Te Chow]

(III) **Broad Crested Spillway** - $Q_s = C L H^{1.5}$ [Ref. pp. 360-362]

$C = 3.27 + 0.4 \frac{H}{h}$; $L = L' - 0.1 N H$

H = Physical Water Head on CREST (h_v not included)

h = Weir Height, L' = Measured Crest Length

Assumptions

For Floods or Peak Flows, $\frac{H}{h} \simeq 0.5$ $\therefore C = 3.47$

$L = 90\% L'$

$$\therefore \quad Q_s = 3.12 L' H^{3/2}$$

(IIII) **Flow over Crest of Dam** - $q_c = 3.475 \left[\frac{y}{y+h'}\right]^{1/2} (H')^{3/2}$ [Ref. pp. 52-3]

q_c = Disch./ft. of width

H' & h' as defined above; $y = h' + H'$

Assumptions

For Floods (flow over dam crest)

$H' = \frac{1}{6} h'$ [note $h' \simeq h + H$ in Item (I) above]

$\therefore y = \frac{7}{6} h'$ & $\left[\frac{y}{y+h'}\right]^{1/2} = \left[\frac{7/6\, h'}{13/6\, h'}\right]^{1/2} = 0.734$

$$\therefore \quad q_c = 2.55 (H')^{3/2}$$

Apply to Crest in steps where levels are roughly const.

METCALF & EDDY, ENGINEERS

Project National Review of Non Fed. Dams Acct. No. 5864 Page 3 of
Subject Worcester, Mass Area Compld. By LEB Date 7/24/78
Detail COES RESERVOIR DAM Ck'd. By [illegible] Date [illegible]

(V) Discharge & Storage Function Summary

Spillway Crest Length = 38' ∴ $Q_s = 118.5\ H_s^{1.5}$

Dam Crest Length = 350'± ∴ $Q_c = 892.5\ H_c^{1.5}$

$H_s = 0$ @ Eleu. 501 , $H_c = H_s - 5.33'$

Above Crest Storage relative to Drain Area = $S = H_s(12''/ft)\left(\frac{0.15}{10.9}\right) = .165\ H_s$

Pond Eleu.	Q_s	Q_c	Q_{Tot}	S	F_{TF}	F_{100}
502	118	—	118	.165		
503	335	—	335	.330		
504	616	—	616	.495		
505	948	—	948	.661		
506	1325	—	1325	.826		3301
506.33	1458	—	1458	.880		3255
507	1741	489	2230	.991		3160
508	2194	1926	4120	1.156		3020
509	2681	3894	6575	1.321	8609	
510	3200	6275	9475	1.486	8436	
511	3747	9007	12754	1.651		

(VI) Outflow Summary

Taken from Plot on Item (VII)

A- Test Flood Peak Outflow = 8500 c.f.s. w/ Pond Eleu. 509.7

B - 100 Year Flood Peak Outflow = 3080 c.f.s. w/ Pond Eleu 507.5

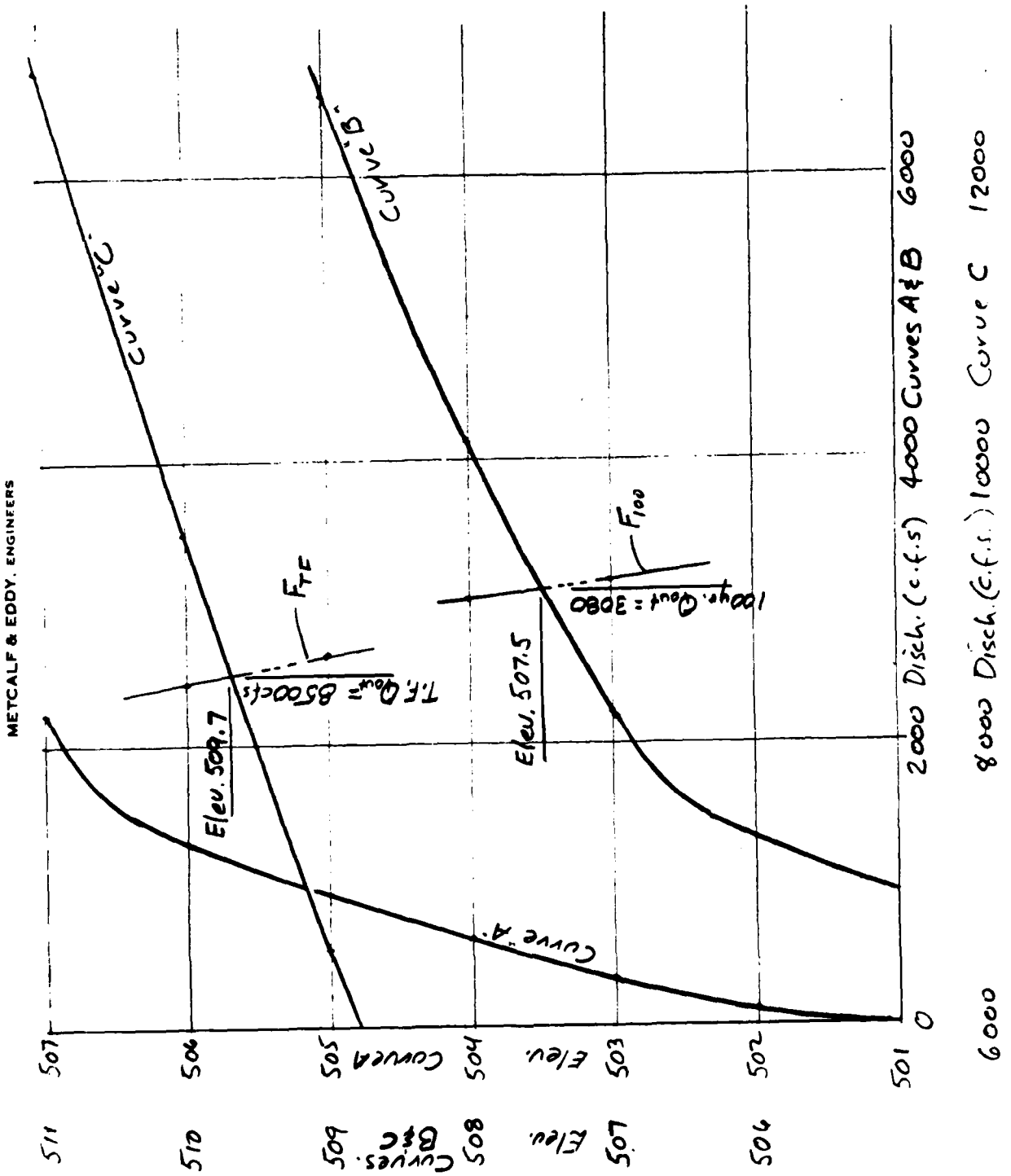
METCALF & EDDY, ENGINEERS

Project Nat. Review of Non Fed Dams Acct No 5864 Page 40 of 6

Subject Worcester Mass. Area Compld By LEB Date 7/24/78

Detail COES RESERVOIR DAM Ck'd By EMC Date 8/2/78

(VII) Discharge & Storage Function vs Pond Elevation



METCALF & EDDY, ENGINEERS

Project Nat. Rev. of Non Fed. Dams Acct. No. 5864 Page 50 of —

Subject Worcester Mass Area Comptd. By LEB Date 7/24/79

Detail COES RESERVOIR DAM Ck'd. By EMS Date 8/2/79

(IX) Peak Crest Flow Conditions

Flow over crest @ Pond Elev. 509.7 = 5460 cfs.

For Crest Length = 350', Crest Flow = 15.6 cfs/ft

Critical Conditions:

$$y_c = \left[\frac{(15.6)^2}{g}\right]^{1/3} = 1.96'$$

$$V_c = \frac{15.6}{1.96} = 8.0 \text{ fps.}$$

METCALF & EDDY, ENGINEERS

Project: Nat Review of Non Fed Dams Acct No 5864 Page 6 of
Subject Worcester Mass. Area Compld By LEB Date 7/24/78
Detail COES RESERVOIR DAM Ck'd By EMG Date 8/2/78

(IX) Failure of Dam

Peak Failure Flow:

Pond Elevation - 509.7
Toe Elevation — 500.0
Y_o = 9.7

Dam Length Subject to Breaching = 200'
$W_o = 40\%(200) = 80'$

$$Q_{P_1} = 1.68\, W_o (Y_o)^{1.5} = 1.68(80)(9.7)^{1.5} = 4060 \text{ cfs}$$

Storage Volume Released:
Storage Above Spillway
Storage Below Spillway
S = Total Storage =

Channel Hydraulics:

$N_1 A_1$

$Q_1 =$; $y_1 =$; $A_1 =$; $Vol_1 =$
$Q_2 =$ $(1 - \frac{\quad}{\quad}) =$ cfs. ; Wave Ht ≅

Time to Drain:
$\frac{43560\ (\quad)}{3600(\frac{1}{2})(\quad)} =$ Hours.

METCALF & EDDY, ENGINEERS

NON REPRODUCABLE PLATE

FREDERICK J. SANGER
CONSULTANT IN CIVIL ENGINEERING
18 BERKMANS STREET
WORCESTER, MASS.

The Coes Knife Co.
Att. Mr. David L. Hall
Chief Engineer

September 18, 1955

Spillway at Coes Reservoir, Worcester, Mass.

Introduction. This discussion is in reply to a letter from Mr. Hall dated September 8, 1955 and in accordance with our telephone conversation of the previous evening.

A. On a letter to Mr. L.O.Warden, County Engineer, from Mr. R.B.MacKinnon, dated April 29, 1955.

1. There can be no disagreement with the statement on the seriousness of a dam failure at Coes Reservoir.

2. The drainage area of 11.9 square miles includes the drainage areas of the Holden and Kendall Reservoirs but not that of Pine Hill Reservoir although that is connected to the others in the Worcester City, Low Service, Water Supply, and should presumably be included. The total area then becomes about 19 square miles of which about 1 square mile is water surface. The reservoirs divert a comparatively small amount of water for consumption but have a big effect in their storage capacity which cannot be allowed for without quite considerable study. I have studied the drainage area and agree with Mr. MacKinnon's estimate for his assumed area, neglecting reservoir storage. The value of 2900 cfs seems reasonable since with a rainfall like that of last month, the storage of perhaps 6" of rain would have left plenty for the spillways (and for the particular spillway under discussion). The Kinnison-Colby formulas are based upon a very thorough study of Massachusetts drainage areas and are probably the best to be used in this region.

The spillway sizes quoted by Mr. MacKinnon are based upon a discharge coefficient of 3 which is what I would use in the absence of model studies or of actual performance figures. His table also neglects the effect of the velocity of flow overthe spillway; this is good practice and the effect is less than half a foot in head, anyway. The coefficient of 3 varies up to nearly 4 and if a new spillway were to be constructed a model test would be well worthwhile to give a high coefficient and hence smaller dimensions than those listed. The table stops at 8 ft depth; if it were continued to 9 ft, the corresponding length would be 36 ft (which is less than what you have now), based upon the same assumptions: if the coefficient could be found more than 3 then the depth could be reduced materially and 8 ft or less would do with a 39 ft spillway.

B. Letter of August 11, 1955 signed by Mr. Aspero.

If Mr. MacKinnon's figures are accepted then this letter requires little discussion except that perhaps the County Commissioners advised by Mr. Warden might be prepared to consider alternative proposals for increasing the spillway capacity.

C. On the past history of the Spillway

The official report on the March 1936 flood states that the water in Coes Reservoir rose to the height of the dam crest and you told me on the telephone that the same thing happened last month. This is astonishing because the gauging station at Webster Street showed a discharge of three times the March '36 maximum whereas your spillway took about the same quantity as before. It is difficult to explain why your dam was not overtopped. I estimate that its maximum capacity is about 2000 cfs and the recent flood was certainly quite exceptional and could be considered to be a "rare" flood in the technical sense (i.e. one that would occur once in 1000 years). The reservoirs must have been favorably drawn down so as to provide a very good storage volume which one cannot count on always. About one third of earth dam failures are caused by overtopping and the risk is too high to rely upon sandbags. The future climate of New England will probably include hurricanes more often than before and I strongly recommend that the spillway capacity be increased.

D. Possible ways of increasing spillway capacity to 3000 cfs.

1. Mr. Marden's proposal of lengthening the spillway, lowering its crest, and installing gates to maintain the water elevation in the reservoir. It would seem better to keep the spillway its present length of 39 ft and to lower the crest a little more. A model study could give the actual value of the discharge coefficient and it is probable that a lowering of less than 2 ft, with a properly designed crest profile would suffice. One foot in depth is worth about six feet in length here.

2. Lengthening the spillway. If the spillway were extended 25 ft, or if another spillway 25 ft long were constructed somewhere else on the reservoir the required extra capacity could be obtained without gates. This seems to be reasonable.

3. Siphon spillways. While unusual, siphon spillways are used successfully. Here it would take four pipes of 36" diameter, or an equivalent cross-sectional area, to take the extra discharge. The pipes or conduits would be installed over the dam at convenient points and could be automatic or manually controlled.

4. If the shores of the reservoir can take an increase of 2 ft in water elevation the raising of the dam would provide an obvious solution; the additional storage capacity of the reservoir would be beneficial downstream also. It is probable that this has been thought of and rejected, however. The dam crest should be raised about 4 ft to make a good job.

F.J.Sanger

F.J.Sanger
Registered Professional Engineer
Worcester. September 18, 1955.

ALDEN HYDRAULIC LABORATORY

WORCESTER POLYTECHNIC INSTITUTE

HYDRAULIC DESIGN
FOR
COES RESERVOIR SPILLWAY
COES KNIFE COMPANY
WORCESTER, MASS.
DECEMBER, 1958

HYDRAULIC DESIGN FOR
COES RESERVOIR SPILLWAY
COES KNIFE COMPANY
WORCESTER, MASS.
At
ALDEN HYDRAULIC LABORATORY
WORCESTER POLYTECHNIC INSTITUTE
December 1958

OBJECT

The object of this study was to determine the hydraulic design for the proposed spillway at Coes Reservoir. The flood discharge to be handled by the spillway was determined at 3000 cfs by Professor Frederick Sanger at the start of the study. This figure was found from the application of the Kinnison Flood Formula and has been checked independently.

APPARATUS

The work was done at the Alden Hydraulic Laboratory where a wooden flume 2 feet square in cross section and approximately 25 feet long was available. The flow into the flume was measured by a 12 x 6" venturi meter. Suitable baffles racked and a raft provided smooth flow conditions in the approach channel to the model.

The spillway cross section and the walls of the model were constructed to a 1/15 scale of wood.

The heads in the model were measured with a hook gage mounted in a stilling well 6 feet upstream from the spillway crest. This corresponds to a point 90 feet out in deep water in Coes Reservoir.

PROCEDURE

In preparation for a test the condition to be represented was first modeled carefully in the flume. The modifications in general were changes to the slope of the spillway shape downstream from the crest, change to the depth of channel approach and modifications to the upstream slope immediately adjacent to the crest itself. The crest was always a Creager and Justin shape.

The zero of the hook gage was checked with quiet water in the pool. The venturi manometer was checked at zero flow.

Then a desired flow was set and a period of at least 5 minutes allowed for levels to become steady. Two readings of the venturi manometer and five of the head gage were then taken. Another flow was then set for a succeeding test.

CALCULATIONS

$$Q = K\sqrt{D}$$

where Q = Discharge in cubic feet per second
K = Venturi meter constant found by calibration
D = Deflection of venturi-manometer measured in feet of water

For the spillway:

$$Q = CBH^{3/2}$$

where C = Discharge coefficient
B = Length of crest in feet
H = Elevation of water surface in pond measured above spillway crest elevation. No corrections for velocity of approach was made.

The Froude model relationships were used in this test since gravity and inertia effects predominate in spillway flow. Viscosity effects are present but considered a "scale effect" or a correction. Viscosity operates to give a slightly reduced discharge for a given head in the model. For the prediction of discharge coefficient the model discharge is therefore a little less than what will be attained in the prototype, and therefore on the safe or conservative side. No corrections for viscosity effects were made in these results.

The model ratio is taken as the ratio of two similar lengths in the model and prototype (subscripts "m" and "p" respectively). For these model tests the ratios or transfer coefficients for the various quantities are as follows:

Quantity	Model Ratio	Description
Length	$R = 15$	By definition
Head(vertical length)	$R = 15$	By definition
Area	$R^2 = 225$	Since Area = $(\text{Length})^2$
Volume	$R^3 = 3375$	Since Volume = $(\text{Length})^3$
Velocity	$R^{1/2} = 3.873$	Since Velocity = $(2gH)^{1/2}$
Discharge	$R^{5/2} = 871.4$	Since Discharge = (Area)(velocit
Roughness "n"	$R^{1/6} = 1.570$	From Manning Formula

RESULTS

A number of tests were made during the study which had no bearing upon the final results, and have therefore been omitted from this report.

The results of the coefficient tests of the spillway section are presented in plotted form in Figure 1.

It will be noted that the coefficient of discharge for the original spillway section was found to be 3.11 at a design head of 5 feet. The coefficient of discharge for the recommended spillway ("c" points) was found to be 3.97 at the head of 6 feet. This is an increase in discharge capacity of 27% per foot of spillway length. The fact that this coefficient of discharge is very close to the normal Creager and Justin value indicates that very little further improvement is possible. The desirable hydraulic design indicated by these tests is given in Figure 2. Briefly the reason for some of these details is as follows:

1. The spillway crest needs a 1/7 slope on the downstream side to achieve the high value of the coefficient of discharge. A flatter slope seriously reduces the discharge. For this reason the crest itself must be located near the downstream side of the dam.

2. The 2 foot depth in the channel approach brought the flow to the spillway crest with very little loss. Shallower depths were tried with a reduction in discharge capacity.

3. A sloping upstream face was given a Creager and Justin profile to reduce the thrust of ice pressure.

4. The 1/4 flare of the sidewalls at the entrance to the short spillway channel was shown by tests to provide the maximum coefficient of discharge. Straight high walls, or straight sloping walls for the flare made no difference in the discharge coefficient. Other degrees of flare both greater and less than the 1/4 showed larger losses and lowered discharge performance.

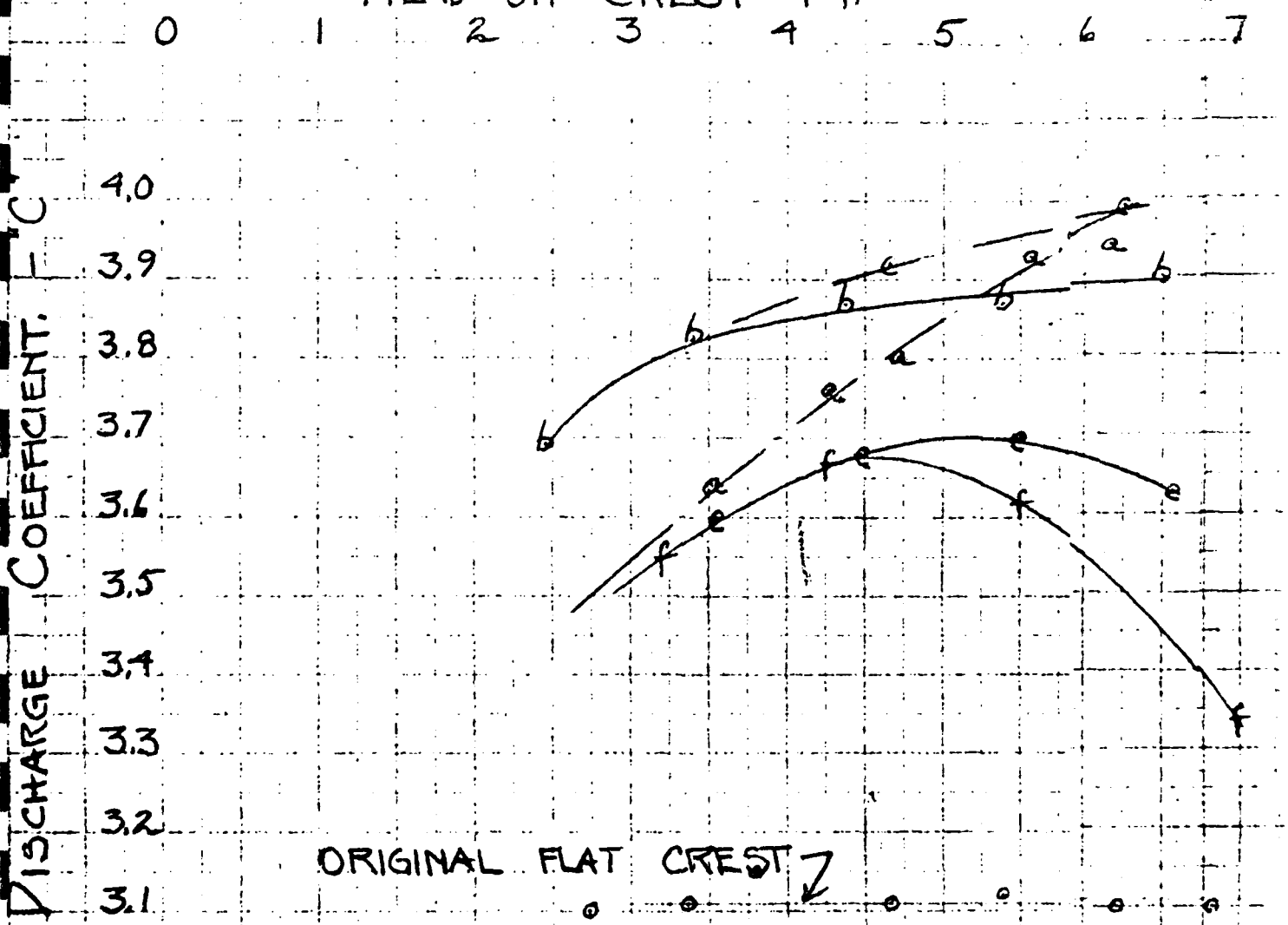
5. After every effort had been made to secure the maximum discharge capacity of the discharge section the length of the spillway was computed from the required flow capacity (3000 cfs), the maximum flow coefficient (3.95) for a head of 6 feet to be 52 feet.

There is no allowance for wave action in this calculation and the maximum discharge of 3000 cfs has been computed with the water level at the top of the dam. The final length should be determined in conference with the County Engineer, taking into account such factors as the effective storage on the Coes Reservoir water shed, the necessary allowance for wave action and the possibility of raising the dam to provide for the added safety against wave action rather than increasing the length of the spillway, whichever provides the most economical answer.

The general arrangement for the hydraulic design is given in Figure 2, and the details of the spillway cross section shape are given in Figure 3.

Very truly yours,

L. J. Hooper



$$\text{DISCHARGE (CFS)} = C\,B\,H^{3/2}$$

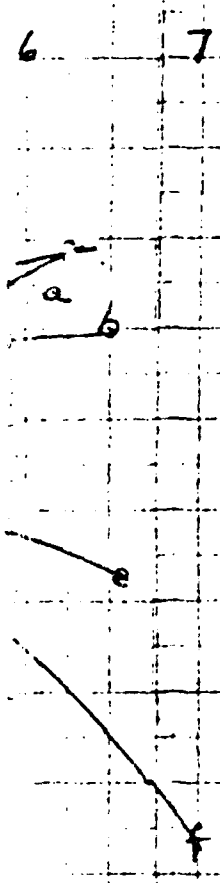
B = CREST LENGTH - FT.

H = HEAD ABOVE CREST - FT.

C = DISCHARGE COEFFICIENT

DESIGN HEAD = 5 FT.

FIG 1



— — CREAGER AND JUSTIN CREST.

e e C & J CREST WITH 1/10 DOWNSTREAM SLOPE

f f " " " " " 1/5D " "

b b C & J CREST WITH 2' DEPTH IN CHANNEL OF APPROACH AND 1/7 DOWNSTREAM SLOPE.

c c AS IN b BUT WITH 1/4 SIDE FLARE ON INTAKE WALLS.

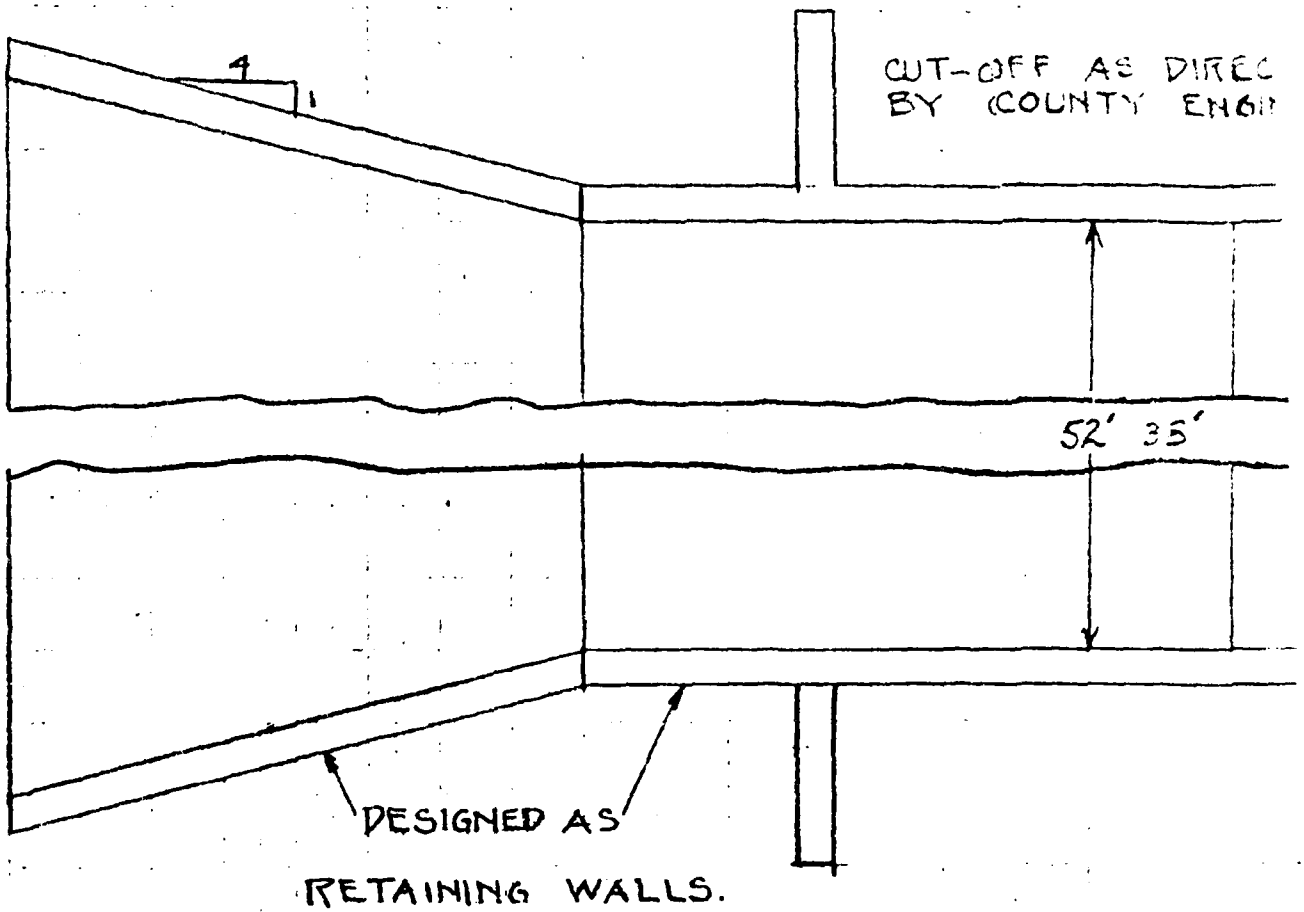
HEAD MEASURED IN DEEP WATER.

NO CORRECTION FOR VELOCITY OF APPROACH

DISCHARGE COEFFICIENT STUDY COES RESERVOIR SPILLWAY.

COES KNIFE CO.
WORCESTER MASS.

ALDEN HYDRAULIC LABORATORY
L. J. HOOPER DEC. 19 1958.


4
1
CUT-OFF AS DIREC
BY COUNTY ENGI
52' 35'
DESIGNED AS
RETAINING WALLS.

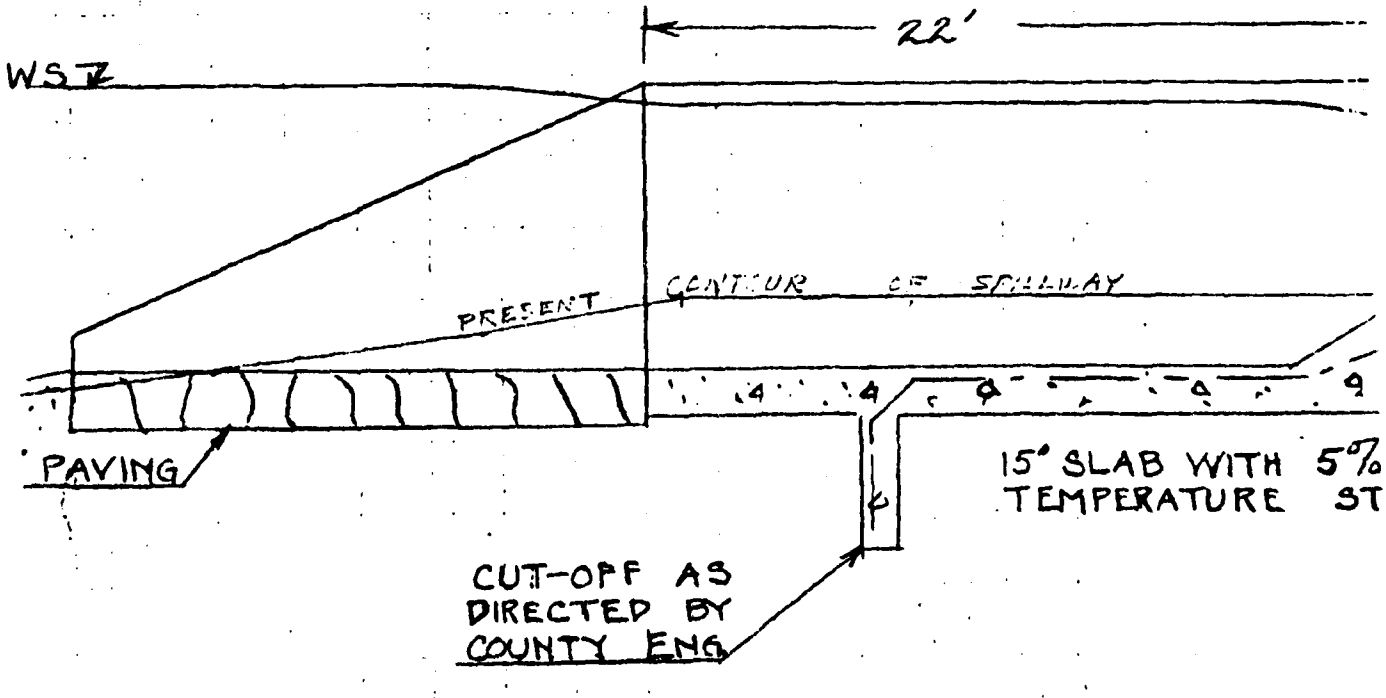
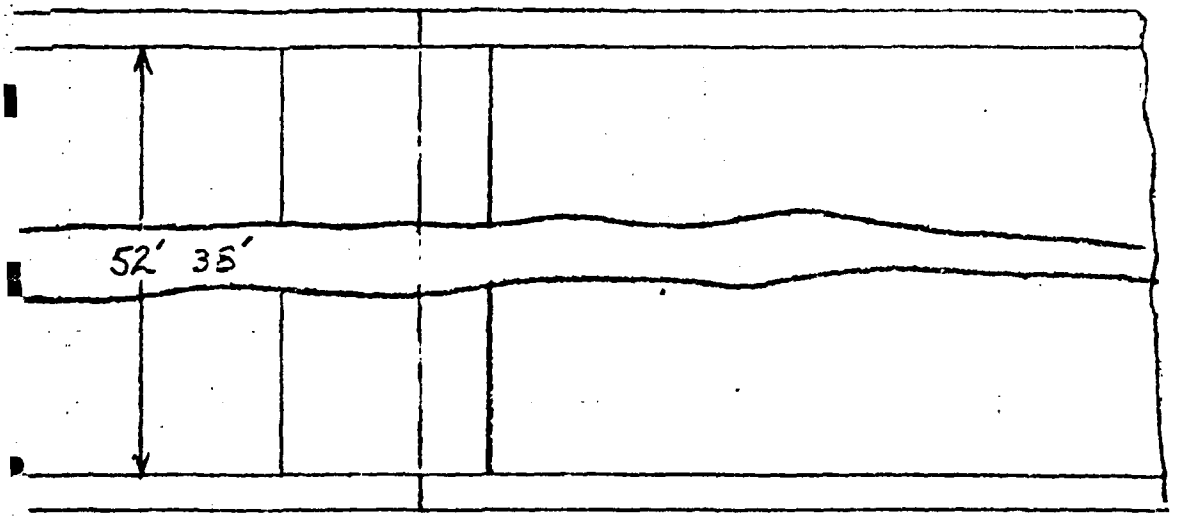
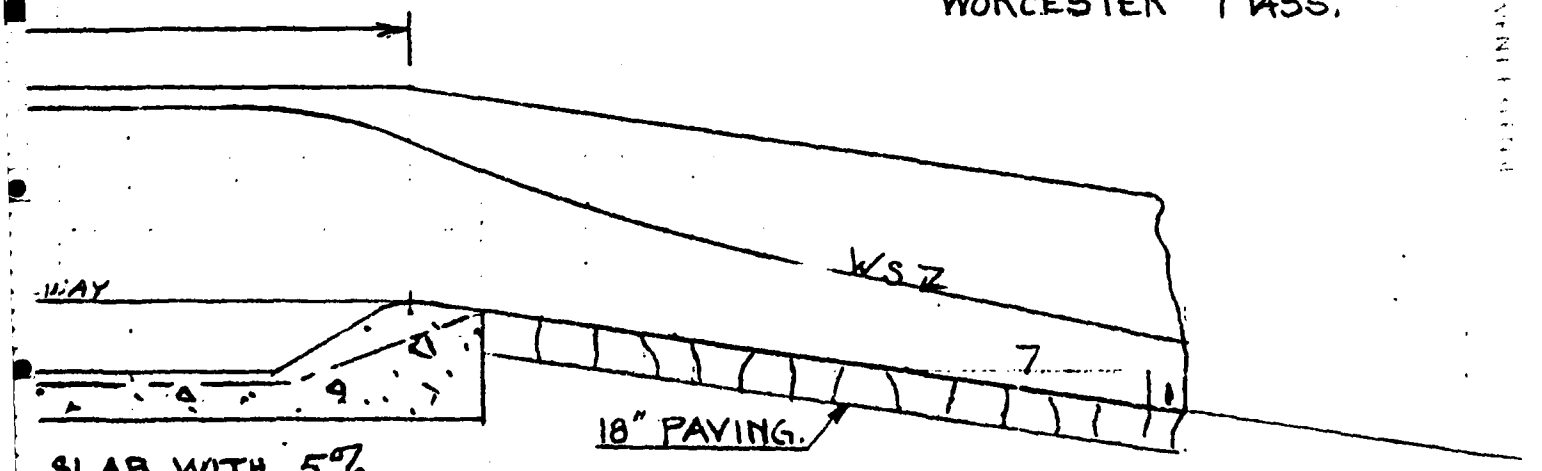

22'
W.S.
PRESENT
CONTOUR OF SPILLWAY
PAVING
15" SLAB WITH 5%
TEMPERATURE ST
CUT-OFF AS
DIRECTED BY
COUNTY ENG

FIG. 2

OFF AS DIRECTED
COUNTY ENGINEER.

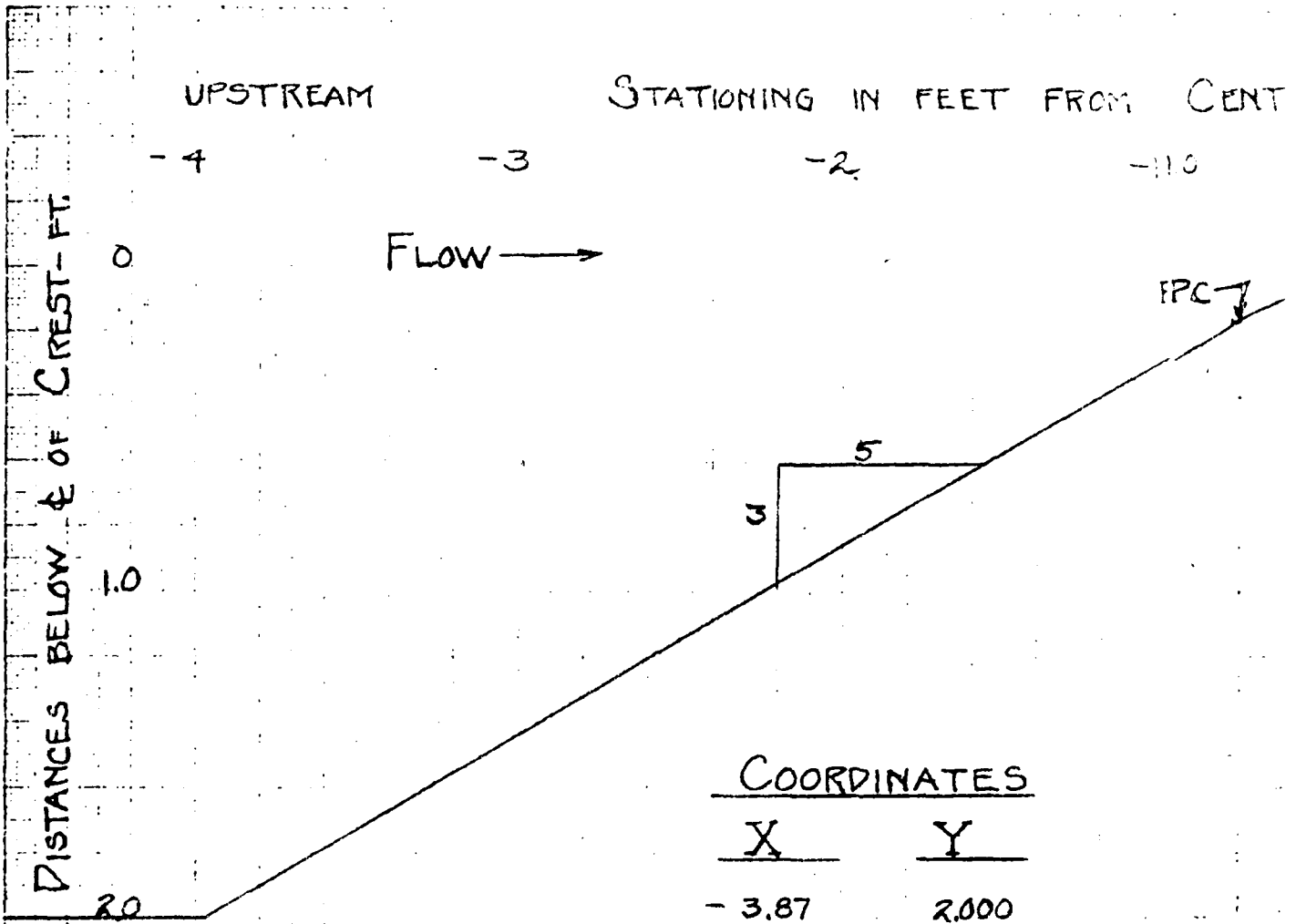


HYDRAULIC DESIGN DETAILS
COES RESERVOIR SPILLWAY
COES KNIFE CO.
WORCESTER MASS.



SLAB WITH 5%
MPERATURE STEEL.

L. J. HOOPER DEC 19 1958



COORDINATES

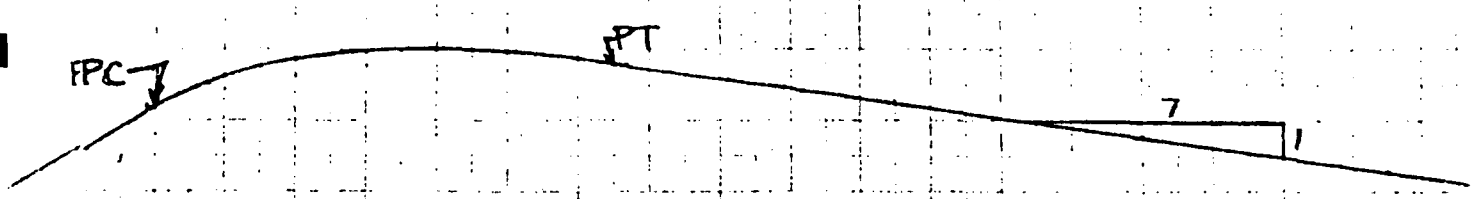
X	Y
- 3.87	2.000
- 0.80	0.162
- 0.70	0.112
- 0.60	0.072
- 0.50	0.047
- 0.40	0.025
- 0.30	0.012
- 0.20	0.005
- 0.10	0.002
0.00	0.000
0.10	0.002
0.20	0.007
0.30	0.017
0.40	0.027
0.50	0.042
7.50	1.042

DESIGN HEAD 5 FT.

FIG

DM CENTERLINE OF CREST. DOWNSTRE

-11.0 0 1 2



SPILLWAY CROSS SECTION
COES RESERVOIR

COES KNIFE CO
WORCESTER MASS.

L. J. HOOPER DECEMBER 19 1958.

FT.

APPENDIX E

INFORMATION AS CONTAINED IN

THE NATIONAL INVENTORY OF DAMS

INVENTORY OF DAMS IN THE UNITED STATES

STATE	IDENTITY NUMBER	DIVISION	STATE	COUNTY	CONGR DIST	STATE	COUNTY	CONGR DIST	NAME	LATITUDE (NORTH)	LONGITUDE (WEST)	REPORT DATE DAY | MO | YR
MA	120	NED	MA	027	03				COES RESERVOIR DAM	4215.0	7150.5	08SEP78

POPULAR NAME	NAME OF IMPOUNDMENT
	COES RESERVOIR

REGION	BASIN	RIVER OR STREAM	NEAREST DOWNSTREAM CITY–TOWN–VILLAGE	DIST FROM DAM (MI.)	POPULATION
01	06	TR-BLACKSTONE RIVER	WORCESTER	0	172300

TYPE OF DAM	YEAR COMPLETED	PURPOSES	STRUCTURAL HEIGHT (FT.)	HYDRAULIC HEIGHT (FT.)	IMPOUNDING CAPACITIES MAXIMUM (ACRE-FT.)	IMPOUNDING CAPACITIES NORMAL (ACRE-FT.)	DIST	OWN	FED R	PRV/FED	SCS A	VER/DATE
REPG	1865	R	21	20	1400	900	NED	N	N	N	N	17AUG78

REMARKS

D/S HAS	SPILLWAY CREST LENGTH	SPILLWAY TYPE	SPILLWAY WIDTH (FT.)	MAXIMUM DISCHARGE (FT.)	VOLUME OF DAM (CY)	POWER CAPACITY INSTALLED (MW)	POWER CAPACITY PROPOSED (MW)	NAVIGATION LOCKS NO	LENGTH (FT.)	WIDTH (FT.)	LENGTH (FT.)	WIDTH (FT.)	LENGTH (FT.)	WIDTH (FT.)	LENGTH (FT.)	WIDTH (FT.)
1	739	U	59	1458	30000											

OWNER	ENGINEERING BY	CONSTRUCTION BY
COES KNIFE COMPANY	LORING COES	

REGULATORY AGENCY			
DESIGN	CONSTRUCTION	OPERATION	MAINTENANCE

INSPECTION BY	INSPECTION DATE DAY | MO | YR	AUTHORITY FOR INSPECTION

REMARKS

END

FILMED

9-84

DTIC